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ELEMENTS OF
Soil Conservation

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Hugh Hammond Bennett

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ELEMENTS OF SOIL CONSERVATION

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Preface

Soil conservation is the youngest of the agricultural sciences. From the very start, practical field work has been supported by a program of research through which new tools and methods of control as well as improvements on present tools and techniques are sought from day to day. As fast as discoveries are made, they are being carried to farmers cultivating lands to which they apply and to the general public.

There is great need for more real soil conservation teaching in our schools, from the lower grades of the public schools on up through the colleges and universities. As soil conservation interest and subsequent soil conservation action have developed progressively from year to year, demands for pertinent information in the form of suitable teaching material have mounted correspondingly.

Farmers' bulletins, technical bulletins, and nontechnical publications along with motion pictures, exhibits, photography, the agricultural press, and the radio have been utilized to present facts widely and thereby provide information on sound conservation-farming measures.

At the request of educators, educational organizations, those concerned with soil conservation districts, and others interested, the Soil Conservation Service has compiled factual information about the nation's resources, erosion, and soil and water conservation. Such material was designed for the use of teachers, authors, and laymen.

This volume undertakes to brief for the student the more

important aspects of the serious problem of soil wastage and methods of soil conservation.

Except where indicated, all photographs, maps, and graphs were made by the Soil Conservation Service or its predecessor, the Soil Erosion Service.

Hugh Hammond Bennett.

Washington, D. C.,
December, 1946.

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Introduction

Economic stability grows from good soil used intelligently. Wise use of productive land means protecting the land from impoverishing influences while under cultivation or grazing so as to keep it permanently productive. To do this, many farmers need the technical assistance of soil conservationists. They also need the support and encouragement of the public.

Basically, the economic stability of both city and rural areas depends on how farmers use their lands. The sooner an understanding of soil conservation permeates the community—through the schools, the churches, the civic organizations, the businesses and industries—the sooner conservation farming can be spread across the land to hold the soil and maintain it for present and future generations and for the security of the nation.

As individuals, communities, and states and as a nation, we need to get better acquainted with the land, its needs, and the practical possibility of taking care of those needs. If we are courageous in accepting new ideas and willing to work with instead of against the land, we shall find in conservation farming an avenue to the best system of agriculture that the world has ever known. What is needed now is the desire and decision to go ahead and do the job. It is being done, but it could be done faster if everybody would help. More and more work will be required, and also cooperation and help. There are no short cuts to conservation of soil and water. Nature made the land; nature turned the rains upon it; and nature fashioned material affairs so that water always runs downhill. We can waste the soil by opposing nature, but we cannot restore the soil after it is lost. We cannot make water run uphill; but by slow-

ing the rate of runoff, we can store a lot of it for crop use on its way downhill, in the reservoir of the soil.

Some of the basic land facts people need to know are as follows:

1. Food comes from soil and nowhere else. Even seafood indirectly comes largely from products of the land.

2. Productive land around the world is scarce and becoming scarcer.

3. Before the First World War, most of the people of the world were always hungry.

4. Hunger is a product of worn-out, unproductive land.

5. Hungry people make fertile ground for sowing the seed of discontent, strife, uprisings, and war.

6. We have left in the United States enough land to take care of us if we take due care of the land, from now on, but we do not have any too much. *Our supply of really good land now stands at about* 460 *million acres.* That is the total—all that we have of really good land, including land now under cultivation, and all that we can put under cultivation with presently practical methods of drainage, irrigation, and other accepted soil practices.

7. *All but about* 100 *million acres of this limited supply—this critical* 460 *million acres—of productive land is subject to the same wasteful process of erosion that already has ruined for further cultivation or severely damaged* 200 *million acres of good land formerly cultivated here in the United States.*

Soil conservation farming is common-sense farming with scientific methods, and it is proving its value. This new type of farming, producing all kinds of crops on millions of acres, has resulted in an average increase in per-acre yields across the country amounting to more than 20 per cent. Consider what this means. If all the farm lands of the country were protected and improved by soil conservation treatment, the resulting in-

creased production here in the United States would equal the additional yield of a sixth farm for every five now in cultivation.

Recently, 9,244 typical farmers throughout the United States who have practiced conservation on all their lands (their cropland, woodland, pasture land, idle land, and even odd corners of land valuable only for wildlife) reported on the benefits that they have derived from conservation farming. These practical farmers, living here and yonder under a wide range of conditions covering nearly all of the more important farming areas of the country—different kinds of land, various types of farming, rainfall, taxation, etc.—kept books on their operations. Their reports, accounting for all the crops grown on their lands, show that there has been an average per-acre increase in yields due to soil conservation farming amounting to 33.5 per cent. For example, they grew 1,389,000 more bushels of corn on 32,000 fewer acres, 14,705 more bales of cotton on 2,892 acres less land, and 778,882 more bushels of wheat on 25,303 fewer acres. As the result of soil conservation work, the production of beef cattle was increased on these farms by 22 per cent in number, dairy cattle by 27 per cent, and hogs by 53 per cent.

Records like these are being repeated on the great majority of farms wherever soil conservation farming is practiced. They give unmistakable evidence of what soil conservation is doing for the nation's production. And more and more farmers are being convinced by the successes of their neighbors. For instance, 6,256 of the 9,244 farmers referred to say that their own conservation work has encouraged 36,926 neighboring farmers to adopt one or more of the features of conservation farming. Of the 9,244 farmers who reported on their results, 3,599 say that they have personally assisted other farmers to install soil erosion control measures on 18,042 additional farms.

Reference to such progress does not mean that we are satisfied with what has been done—not at all. The major part of

the job is still ahead. A huge toll of productive land is still being taken by erosion—nearly 500,000 acres every year. We are not working fast enough. The nation-wide program needs the assistance of every American and every agency that can make any contribution. On an acreage basis, scarcely 10 per cent of the soil conservation job was completed in 1945. That is the mathematical situation. Actually, however, if we believe that education, public understanding, basic research, program momentum, and similar important considerations are part of the total job, as I think they should be, then we have gone much farther than 10 per cent of the way toward the goal. Now we know what to do and where the ailing lands are located. We know the meaning of conservation farming, and it is finally getting into the blood stream of millions of farmers. All this constitutes a powerful force for acceleration.

Where good covers of dense vegetation and good stands of forest have been established and maintained, as on steep, erodible land retired from cultivation, there usually is no further need for protection against erosion. The losses of soil under such sound protection are negligible, often too small to measure, and the runoff of rainwater is also much less.

For example, the average annual loss of soil under continuous corn growing on the principal regional soil at the Zanesville, Ohio, Erosion Station has been at the rate of 94.6 tons per acre, and the accompanying loss of water has averaged 42.4 per cent of the total precipitation. Under grass, corresponding losses on the same kind of land have been 0.02 ton of soil per acre (a loss only 1/4,730 as much as under corn) and 4.8 per cent of the rainfall (or about $\frac{1}{9}$ as much as under corn). During a single period of heavy rainfall (nearly 11 inches falling at the Zanesville station during January, 1937, just before the record Ohio River flood) the measured loss of water as immediate runoff from a gullied corn field on this station amounted to

94.7 per cent of all the rainfall, whereas only 31.5 per cent ran off from woodland, and 25.8 per cent ran off from bluegrass.

Similarly, losses under good rotations, combined with terracing, contouring, strip cropping, or all of these practices, have been much less than under straight corn production and other wasteful ways of farming.

These losses are from measured tracts of land, usually small tracts, that probably come close to representing average regional land conditions. At any rate, they constitute a part of the landscape upon which rain falls and courses away to the regional streams in amounts and rates that depend to a large degree on how the farmer uses his fields, pastures, and woods.

Other measurements at the Zanesville station, and at many other similar experiment stations throughout the country, show that conservation treatment continued to lessen runoff and soil loss in some degree, regardless of how long or how heavily it rained and regardless of freezing, thawing, and dry spells.

The soil-loss studies at the Zanesville station are typical of the practical research being carried out by the Soil Conservation Service and cooperating agencies. Soil conservation research is conducted side by side with actual field operations in many cases, and the research staffs in experiment stations and laboratories throughout the country are engaged in working out the best possible solutions to the practical problems encountered in the field in the actual application of conservation measures.

In itself, the simple existence of knowledge is a matter of small value. Only as knowledge becomes widely available, in such form or language as to be readily usable, does it provide a service. This has been amply demonstrated during the recent progress of soil conservation.

Early attempts to initiate erosion control work in communities where farmers and businessmen had not been given the facts about erosion and conservation in any understandable way

proved to be more or less abortive. In other communities, where preliminary work was undertaken to present simple factual information to the farmers and others, the subsequent initiation of conservation operations proved successful. Although no direct analysis has been made, there is reason to believe that the degree of conservation progress and conservation understanding in any given community is directly proportionate to the attention to and proficiency of informational work among the farmers and other citizens of that community.

In the larger volume "Soil Conservation"[1] (by the author), the 73 important problem areas in soil conservation are shown on the map on page 62. The same volume shows the location of the 10 major physiographic regions of the country in Chaps. XXX to XXXIX, inclusive, and describes the principal features of topography, soil, climate, vegetation, erosion, and types of agriculture and the more important methods of soil and water conservation characterizing the 73 main subdivisions of these regions.

Greater detail with respect to topography, climate, and soils can be found in the *Atlas of American Agriculture,*[1] prepared by O. E. Baker, C. F. Marbut, F. J. Marschner, J. B. Kincer, and W. G. Reed of the United States Department of Agriculture and published in 1936.

[1] These volumes can be found in many of the libraries of the country.

CHAPTER 1

The Erosion Problem in the United States

PRESENTING:

- The Virgin Land of America
- Rapid Settlement of the Country
- Waste of Natural Resources
- The Process of Soil Erosion
- Soil an Irreplaceable Resource
- Losses of Plant Food
- Subsoil Farming
- Other Damage by Erosion
- Cost of Erosion
- Need for Erosion Control
- Methods of Erosion Control and Water Conservation
- Responsibility for Soil Defense

The Virgin Land of America. The earliest settlers arriving on the North American continent found a land richly endowed by nature. The natives had done little to cultivate this land or change its virgin character. Before the gaze of the transplanted Europeans lay a vast wilderness teeming with what seemed to be inexhaustible stores of game, fish, fur, timber, grass, and soil. Nearly everywhere, the fertile land supported some kind of vegetation: trees, grasses, shrubs. In all but a few scattered barren areas, dense stands of perennial plants sheltered the ground from the elements and enriched it with their decaying leaves and litter. Soil nourished vegetation; vegetation, in turn, protected and nourished the soil.

Rains fell on the land, and snows melted with the changing seasons; but the water moved slowly over the ground surface,

checked and kept clear by the cover of living and dead vegetation. The deep, soft topsoil, rich with spongy vegetable matter and punctured with the holes of decaying plant roots, burrowing earthworms, insects, and animals, soaked up the rains. The water then filtered down to nourish the growth of vegetation or to replenish underground reservoirs and springs. In general, streams ran clear, and floods were not so violent. Top soil was removed from the land surface no faster than it was built up from beneath by nature's slow method of building soil from the materials of the subsoil.

Rapid Settlement of the Country. Into this virgin land, the colonists entered with energy and enthusiasm. They began a transformation of the earth's surface that is probably without parallel in history. The continent was quickly occupied by explorers, adventurers, trappers, prospectors, miners, loggers, stockmen, and farmers. Along the line of this rapid advance from the Atlantic to the Pacific, there was little thought either of conserving or of wasting resources. With a country of such immense natural wealth, it is small wonder that the colonists thought only of helping themselves to whatever they found.

For a time, the advance was checked by an extensive belt of forest land extending from the Atlantic a thousand miles westward to the region of the prairies. Cutting, girdling, and burning areas of timber called for hard work and required patience. For more than a hundred years, settlement was largely confined to a relatively narrow strip along the Eastern seaboard. Eventually, however, with the pressure of new population from Europe, the westward march began. Moving slowly at first, the pioneers set to work on the virgin forests with axe and fire. Little by little, the land was cleared for farmsteads; vast quantities of timber were burned at the "log rollings" of the settlers. Trails and roadways were opened into the heart of the continent.

Then, across the grasslands bordering the Mississippi, north of the Ozarks, the migration moved at swifter pace. Over vast areas, the prairie sod of the tall-grass country was broken out. Before long, the short-grass country of the Great Plains was also invaded, first by buffalo hunters, then by ranchmen, and finally by farmers. By 1890 to 1900, most of the better lands within the borders of the United States had been settled. A little more than 200 years after the beginning of the westward movement, the last frontier was occupied.

History records the daring of the early pioneers, who blazed the trail for a new nation, and the suffering of the settlers who followed. In many respects, it is a thrilling story of adventure, hardihood, and courage; for the march across the continent was accomplished in the face of great odds and sometimes at tragic costs in life and human misery. It was followed by rapid development in agriculture, industry, commerce, transportation, and communications which finally produced one of the greatest nations on earth.

Waste of Natural Resources. Settlement of the new country was accompanied, however, by huge wastage of the resources with which nature originally endowed the land. The white inhabitants of this new country, in their "conquest of the wilderness" and their "subjugation of the West," piled up a record of wastage and destruction that almost staggers the imagination. Slopes once clothed with magnificent forests now lie bare and stark. Formerly rich lands are riddled with gullies (Fig. 1). Level plains country that once supported lush stands of native short grasses is overgrown with weeds or covered with shifting sands left in the wake of dust storms—not all of it, parts of it.

What caused this tragic transformation? What happened to the bountiful land that inspired early explorers and beckoned settlers to the Pacific? The answer lies largely in a false philos-

ophy of plenty and a myth of inexhaustibility, which prevailed generally for many years and persists among some people even at the present time.

Yet in the time of our forefathers, this was a normal and perhaps an inevitable reaction to the conditions. Nearly every-

Fig. 1.—This maze of gullies, which crosses an entire county in the Southern Coastal Plain and cuts through portions of two adjoining counties, has permanently destroyed more than a hundred thousand acres of some of the best land in the locality. The original gully began about 70 years ago with the drip from a barn roof. The wash was neglected and so extended into a cultivated field. Stewart County, Georgia.

where, the early settlers found rich farm and grazing lands in abundance (Fig. 2). They stretched away as far as the eye could see. There was every reason to believe that the agricultural domain of America was limitless and inexhaustible. Free land extended to far horizons. Occupation was encouraged by the Federal government, by the territories and states, by railroads and land companies. "Go west," and take your choice

of free land or cheap land was the advice to young and old. Nearly everybody advised that course of action.

For a hundred years, the settlers moved westward by oxcart, covered wagon, and railway. For a hundred years, the hurried settlement of the country west of the Alleghenies absorbed the

Fig. 2.—The trees, underbrush, and mat of leafmold in this Maryland area of virgin woodland have anchored this soil safely to the landscape. Nearly all the rainfall is absorbed.

rapidly increasing population of the nation. It was only natural that those who took over the West, like those who occupied the East, should look upon the grasses of the virgin prairies, plains, and tablelands and upon the trees of the valleys as little more than obstacles in the way of human progress.

Much of the land was abused, and the native wildlife ruthlessly destroyed. Buffaloes were slaughtered for their hides and tallow. Trappers took their harvest of pelts without restraint. Forests that protected sloping hillsides and entire

watersheds were cut down in order to plant corn, tobacco, and other crops. Immense areas of grassland were plowed up by the onrushing settlers.

The story of the passenger pigeon is characteristic of this era. The last of these birds, "Martha," died in a Cincinnati zoo in September, 1914. Ornithologists say that once this species was one of the most abundant game birds ever known in any country. Their flights frequently darkened the skies; the branches of trees are said to have been broken off by the very weight of their numbers settling to roost. Yet within a few generations, the legions of this species have been effaced from the earth. From Petoskey, Mich., it is claimed that five carloads of the pigeons were shipped to market every day for 30 days. This means a total of 14,850,000 birds. Should man dwell upon this planet for millions of years, he will never behold another passenger pigeon. They were made extinct through exploitation of the wealth with which nature stocked America!

In like manner, other valuable resources have been exhausted and continue to be exhausted. The final result in terms of the national economy cannot be foretold. One fact, however, is clear enough. The potential wealth and living standard of this nation or of any great nation depend ultimately on its store of natural resources. If through carelessness, neglect, or waste, these resources are dissipated beyond a certain point, the national welfare must be impaired—disastrously, if waste is not halted.

The Process of Soil Erosion. From the long list of nature's gifts to man, productive soil and water are most necessary to human life. *Topsoil* is the most vital part of soil. Lying at an average depth, normally, of about 7 or 8 inches over the uplands of the nation, this upper layer of the soil is the principal feeding zone of the plants, which provide food for human or livestock consumption, fiber for clothing, and timber for shelter.

Soil constitutes the physical basis of our agriculture. Under many conditions, unfortunately, it is one of the most unstable of all major natural resources. Water or wind, in moving across the ground surface, picks up soil particles and carries them away in suspension. Under natural conditions as pointed out previously, dense vegetation retards this movement of soil to a pace so slow, generally, that new soil is formed from the parent materials beneath (*subsoil* materials) as rapidly as the finished product (topsoil) is carried away from above. Under such conditions, the removal of topsoil is known as *normal erosion* and is sometimes referred to as *natural erosion, geological erosion,* or the *geologic norm of erosion.* Geological erosion is a normal process, proceeding with the tediousness of centuries. It cuts away the land at one place and builds it up (by deposition) at another. In slowly sculpturing the land, it contributes material for the development of *alluvial plains* (stream-deposited soil) and *aeolian deposits* (wind-deposited soil).

But where the land surface is bared of protective vegetation, as it must be under cultivation, the soil is exposed directly to the abrasive action of the elements. Thus stripped of the cover that normally holds soil against wind and against water, soil material frequently is moved a thousand times faster than under natural conditions. This accelerated removal of soil is known as *soil erosion.* Unless steps are taken to check its progress, it becomes the most effective agency of land impoverishment.

National habits of waste in this country have nowhere been more flagrant than in the use of agricultural land. It is estimated that erosion in the United States has ruined or seriously damaged about 282 million acres of crop and grazing land. And 775 million acres more of crop, grazing, forest, and other lands have been affected in some degree.

If only cropland is considered, erosion has ruined about 50 million acres for further practical cultivation. Another area of cropland approximating 50 million acres is bordering on the same condition. Nearly 100 million acres more, still largely in cultivation, have been severely damaged by the loss of about

Fig. 3.—Severe erosion in this Oklahoma field where the crop rows ran downhill.

half to all of the topsoil. On at least another 100 million acres of cropland, erosion is getting actively under way.

When the details are examined, it must be admitted that there was in this country much inferior land to begin with, some of it so obviously poor that it has never, to this day, been touched by the plow. Vast areas in the West were too rough, too steep, too stony, too salty (*alkali land*), or too arid for any use other than limited grazing or forestry. In the East, large tracts were too steep, too stony, too wet, or too sandy for profitable cultivation.

Nevertheless, many fundamental principles of sound land use were grossly violated; tens of thousands of acres of exces-

sively steep land were plowed indiscriminately. Within 10 to 50 years more or less, the soil, in numerous localities, has been washed away from millions of acres, and a condition of permanent or near permanent ruin is the result. Even where the land itself was not too steep for a limited and conservative agriculture, farmers waded in with plow and axe, stripped nature's protective cover from the ground (Fig. 3), and without regard for the future, laid bare great areas of the rich soil to the forces of erosion. This was land which might easily have been protected, and the damage was not done maliciously but simply without thought of the consequences—a sin of ignorance!

Soil an Irreplaceable Resource. Lack of foresight and restraint, starting in the early Colonial period and continuing through the present day, has created in this country a land problem of tremendous implications. The situation is grave because of the irreplaceable nature of soil. Once this valuable asset leaves a field, it is as irretrievably lost as if consumed by fire in so far as that particular field is concerned. It cannot be hauled back economically even though temporarily lodged only a short distance down the slope; at least farmers in the United States do not haul it back. A thousand tons would be required to cover an acre to a depth of 7 inches.

Soil is reproduced from its parent material so slowly that we may as well accept as a fact that once the surface layer is washed off, land so affected is, from the practical standpoint, generally in a condition of permanent impoverishment, depending considerably on the character of the exposed subsoil. As nearly as can be ascertained, it takes nature under the most favorable conditions, including a good cover of trees, grass, or other protective vegetation, 200 to 1,000 years or more to build a single inch of topsoil from the raw materials of the subsoil, depending on climatic conditions and nature of the subsoil material. When a 7-inch layer of topsoil is allowed to wash away, there-

fore, at least 1,400 to 7,000 years of nature's work goes to waste. The time involved may be much longer; the building of the second inch may require many more years than the building of the first inch at the surface, and so on downward. Studies of old eroded areas abandoned to trees or other types of vegetation indicate that the building of soil by the natural process generally proceeds from the surface downward. Measurements of the rate of topsoil building in such areas, checked against the age of trees that have grown up since abandonment of the land, have given a clue as to the slowness of natural soil replacement.

Available measurements indicate that more than 3 billion tons of solid material are washed out of the fields and pastures of America every year, enough to load a freight train that would encircle the earth eighteen times at the equator. Millions of tons are poured into the oceans and into reservoirs, stream channels, harbors, and ditches. Vast quantities are piled up along lower slopes or deposited over rich, flat lands of stream bottoms.

Losses of Plant Food. The huge quantity of soil wasted every year contains more than 90 million tons of the five principal elements of plant food: phosphorus, potassium, nitrogen, calcium, and magnesium. This is computed by averaging analyses of many samples of surface soils collected throughout the country (1.55 per cent potash, 0.15 per cent phosphoric acid, 0.10 per cent nitrogen, 1.56 per cent lime, 0.84 per cent magnesia). Of this total, 43 million tons consist of phosphorus, potassium, and nitrogen, the principal ingredients of commercial fertilizer.

Furthermore, erosion removes not just the plant food but the entire body of the soil—plant nutrients, humus, beneficial microscopic organisms, and all other inhabitants and constituents. Consider the further fact that plant food can be restored to soil worn lean by cropping or *leaching* (solution and removal of constituents by rainfall percolating down through the soil); but when the soil itself is washed into the streams and oceans, na-

ture can rebuild its counterpart only after centuries of activity.

Subsoil Farming. Erosion-exposed subsoil can sometimes be successfully cropped. But it nearly always is much poorer and often is practically worthless or even sterile.

Where farmers operate on land stripped of its vitally important surface layer of mellow topsoil (Fig. 4), they frequently

Fig. 4.—Subsoil. Hard, dry, and baked by the sun, this land has little value for productive purposes. The topsoil was blown off this Texas field to the depth of plowing.

have but the slimmest opportunity to make a satisfactory living, whether prices of their products are up or down. In short, they have been reduced to the unfortunate status of subsoil farmers, and subsoil farming too often is the equivalent of bankrupt farming on bankrupt land.

Other Damage by Erosion. Besides impoverishing and ruining farm land, erosion has indirect consequences that threaten the permanence of investments amounting to billions of dollars in navigation, power, municipal water supply, and drainage

and irrigation developments. Products of both surface wash and gully excavation are carried away by storm waters and often deposited in stream channels or reservoirs. Yawning gullies concentrate rainfall and discharge it at maximum speed to gorge the channel ways of streams with destructive floods. As erosion strips away the absorptive top layers of soil, rainwater encounters greater resistance in penetrating the less permeable layers of clay lying beneath. In many sections of the country, the effects of drought on plant life have been greatly aggravated by progressive soil removal.

Cost of Erosion. The monetary direct cost of erosion to farmers in the United States is estimated at not less than $400,000,000 a year.

Roughly estimated annual losses are

Direct cost to farmers		$400,000,000
Damage to highways		180,000,000
Damage to railways		100,000,000
Damage to reservoirs		30,000,000
Approx. no. depleted by silting	2,200	
Per cent of approx. 8,000 not now depleted that will be depleted in less than 50 years	39	
Damage to navigable streams and harbors (cost of dredging, fiscal year 1939)		29,000,000
Damage to irrigation ditches		18,000,000
Damage to drainage ditches		15,000,000
Contribution of erosion to increased flood damage:		
A. 25 per cent average property damage by major floods		12,000,000
B. 50 per cent of damage by minor floods:		
1. Principally to crops on about 800,000 acres subject to annual overflow		6,000,000
2. 50 per cent to property, mainly bridges, fences, farm buildings and livestock		24,000,000
Damage to wildlife		5,000,000
Damage within cities (sediments, stream-bank erosion, etc.)		25,000,000
Total of Major Items		$844,000,000

(Other damages occur, such as depletion of fish in streams, damage to oyster industry, and removal of potential plant food constituents in eroded topsoil, probably worth around $3,000,000,000 annually.)

Need for Erosion Control. As matters now stand, control of erosion is the first and most essential step in the direction of correct land use on about 75 per cent of the present and potential cultivatable areas of the nation. Looking to the future, one realizes on the basis of past experience that within the next hundred years the United States could lose another 100 million acres of its remaining valuable agricultural land or have that much severely impoverished by erosion unless adequate protection is provided. If permitted to continue unchecked, such progressive impoverishment eventually would reduce the area of *good cropland* from the present total of about 460 million acres to not more than 75 to 100 million acres. Such an area would be insufficient for our national requirements. The ruin of another 100 million acres could endanger our national standard of living and spread poverty and malnutrition across the nation.

Beyond a hundred years, which is not a long time in the life of a nation (or should not be), rain and wind will still be moving soil from vulnerable areas that may be left unprotected.

In other words, accelerated soil erosion presents the nation, not merely the individual farmer, with a physical land problem of enormous importance to its continuing welfare. Without permanent safeguards for our productive land, there can be no permanent agriculture; and without a permanent agriculture, this nation can scarcely be expected to continue a vigorous existence.

Moreover, beyond this whole land problem exists the intimate physical relationship of eroding land to mounting flood heights and to damaging silt deposits. No permanent solution of the latter two problems appears possible without better control of runoff all the way from the crests of ridges down across the watersheds—fields, pastures, and woodlands—where floods originate and silt loads are picked up, on to the very channel ways of streams and rivers. Control of runoff means control of erosion; one necessarily involves the other.

Methods of Erosion Control and Water Conservation. Over a period of many generations, farmers in America and in foreign lands have developed, largely by a process of trial and error, a number of devices and practices for the control of erosion and the retardation of runoff. In recent years, specialists have studied these measures, tested their effectiveness under varying conditions, and made valuable improvements. They have also developed new methods and devices for control and prevention. Today there is a practical solution or a partial solution at least for virtually every kind of erosion problem with which the farmer or stockman may be confronted.

Responsibility for Soil Defense. The responsibility for the control of erosion falls upon both the nation and the individual. National responsibility involves the protection of society's interest in a natural resource of vital importance to the whole people. Government functions properly in discharging this responsibility. Equally strong, however, is the interest of the individual in the land that he owns. National action may be led and aided by government, but ultimately the soil must be largely conserved by those who till the land and live directly by its products. Without a widespread recognition of this responsibility, any governmental program of soil conservation is likely to fail.

Questions

1. What was the land of America like when the colonists arrived?
2. Describe the settlement of the area now comprising continental United States in relation to conservation of natural resources.
3. When did the American frontier days cease?
4. Why was wastage of America's natural resources so rapid?
5. How did the settlers value land? Timber? Wildlife?
6. What is soil erosion?
7. How much land has been ruined for cultivation in the United States?

8. When soil is washed away, can it be replaced?

9. What is the difference between soil impoverishment by erosion and by cropping?

10. Define subsoil farming.

11. What is the estimated direct cost of soil erosion to the farmers of the United States?

12. Why is control and prevention of soil erosion so critically needed?

13. What does erosion remove from land besides plant food?

14. Why does the nation have a responsibility in conserving soil?

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CHAPTER 2

Extent of Erosion

PRESENTING:

Public Recognition and Significant Developments
Soil Erosion Service Established
First Comprehensive Soil Conservation Act
Wide Extent and Seriousness of Erosion
Areas Affected
Seriousness from Place to Place
Some Examples of Erosion-depleted Land

Public Recognition and Significant Developments. Only in the past few years have the far-reaching effects of the soil-erosion problem in the United States received widespread attention. As recently as 12 to 15 years ago, soil erosion was commonly regarded as little more than a local problem confined to those farms where the land for some unexplained reason was subject to excessive washing. Except in some of the Southern states, the average farmer seldom consciously did more to check the wastage than follow the generally ineffective practice of throwing a little brush or rubbish into his most troublesome gullies. With this, he usually dismissed the problem until the appearance of the next deep gully or group of deep gullies.

The average city dweller knew nothing about the problem and so never gave it a thought. Generally speaking, the idea that soil erosion was steadily undermining the physical basis of the nation's agricultural enterprise never occurred to the

American farmer or to the educator, legislator, or professional man. And everywhere scientists for the most part failed to sense the full effects of erosion or to relate to it soil depletion, land abandonment, and migration of farmers. The idea that soil wastage was anything more than a matter of the mechanics of farming was generally rejected as the most apparent kind of nonsense.

Outside a few localities in the United States where the problem of erosion literally forced its attention on land users, as in parts of the Cotton Belt, little or no recognition was given the problem, and practically nothing was done about it. An awakening came, finally, through an educational and investigational program inaugurated by the United States Department of Agriculture and some of the states about 1930.

Soil Erosion Service Established. In the fall of 1933, the Soil Erosion Service was established. This organization set out immediately to undertake demonstrations of practical erosion control and rainfall conservation throughout the nation. The undertaking had widespread effect in arousing farmer interest. Then on May 12, 1934, the nation witnessed a disturbance that was completely without precedent in American history. Dust clouds rising over sun-parched fields in western Kansas, Texas, and Oklahoma and adjacent parts of New Mexico and Colorado were lifted into the pathways of high air currents and carried eastward across two-thirds of the continent. For the first time since the coming of white man to America, soil from the Great Plains darkened the sun over the nation's capital, sifted through the screens of tall office buildings in New York City, and moved on for hundreds of miles over the Atlantic Ocean. People on the eastern seaboard were shocked into a realization that something had gone wrong with the land to the west. All over the country, people of both city and country began to inquire about the new phenomenon, discuss its mean-

ing, and offer suggestions for curbing the depredations of erosion.

First Comprehensive Soil Conservation Act. Then came, in 1935, an act of Congress setting up the Soil Conservation Service as a permanent agency to conserve the basic soil resource of the nation through control and prevention of erosion and runoff. Adoption of this act (*Public* No. 46, 74th Congress), the first Soil Conservation Act of the United States, constituted national recognition of the erosion problem in a fully comprehensive manner by the Congress and provided legal means for the solution of the problem.

Wide Extent and Seriousness of Erosion. Soil erosion is now generally recognized in the United States as a powerful and destructive force that, directly or indirectly, affects the lives of every man, woman, and child. It is understood now not as a freak of nature which occasionally turns up on isolated farms and ranches but as an almost continually active process that attacks countless fields and pastures, whole watersheds, and broad farming communities. Evidence of its damaging effects has been discovered over an area comprising approximately a billion acres of crop-, grazing, forest, and abandoned lands of continental United States. It has extended into nearly every major farming region and has affected, in some degree, the production of nearly every staple crop that we produce.

Areas Affected. Completely accurate statistics of the total land area in the United States affected by soil erosion and the degree of damage have not been fully acquired. The task of making a detailed, nation-wide survey is so vast that many damaged areas doubtless would increase in extent or depth of soil removal before the study could be completed. However, much information is now available pertaining to the extent and seriousness of the problem, gathered through the 1935 erosion survey of the United States (made by the Soil Conservation Ser-

vice in cooperation with the states), through scattered detailed erosion surveys, and by actual measurements of soil losses made at erosion experiment stations located in important problem areas of erosion damage. By combining and weighing all this

Fig. 5.—Formerly cultivated good land ruined by gullying. Poor subsoil material washing from such areas damages good bottomland downstream. Local control of such wasted land provides protection for remote areas. North Carolina.

information, it is possible to estimate with a reasonable degree of accuracy the areal extent and seriousness of the erosion damage.

The 50 million acres of former cropland in this country, previously referred to as having been ruined by erosion (Fig. 5), is an area about the size of the state of Nebraska, and it cannot be considered for purposes of further practical crop use. Most of this land already has been abandoned; a few patches here and there still support a sparse population in a condition of essential poverty. Most of the area was formerly productive

land, giving good yields generally without the use of fertilizers. Now, it is so completely stripped of topsoil or so badly dissected by gullies that farming is either unprofitable or physically impossible.

Fig. 6.—Land ruined by gullies. This land should be retired from cultivation, Mississippi.

The other 50 million acres of very severely eroded land referred to, is in nearly as bad condition as the first 50 million, bordering on a condition of practical uselessness. Most of it is already poor land and should be retired from cultivation (Fig. 6). It cannot properly be appraised as worth-while cropland.

Much of the second 100 million acres referred to as severely impoverished land is still in use, although nearly all of it has lost a fourth or more of its original topsoil; some of it has lost as much as three-fourths and some all of the topsoil. Unless

immediate steps are taken, the larger part of this land will be useless or too poor for profitable farming in a relatively short time. Much of it is so poor now that nature can probably do as good a job toward rehabilitation as man.

Fig. 7.—Erosion by a heavy rain following a forest fire. Northern Idaho.

Finally, there is an indeterminate area of cropland, probably amounting to well over 100 million acres, where erosion just recently has begun to make active progress.

Erosion, however, is not confined to cropland alone. It occurs also on an enormous aggregate area of overgrazed range in Western United States. Fires and close grazing have produced severe erosion in woodland areas (Figs. 7 and 8).

Including these eroded areas with the eroded croplands and excluding only rugged mountains, desert, and badland sections, a total of 282 million acres, as previously pointed out, have been ruined or severely impoverished, and an additional area of 775 million acres of various kinds of land (crop-, grazing, and forest

lands, mainly) are being affected to some extent by erosion at the present time or have already been affected.

Thus, more than half of the 1,904,000,000 acres comprising the total land area of continental United States already has been somewhat affected by erosion.

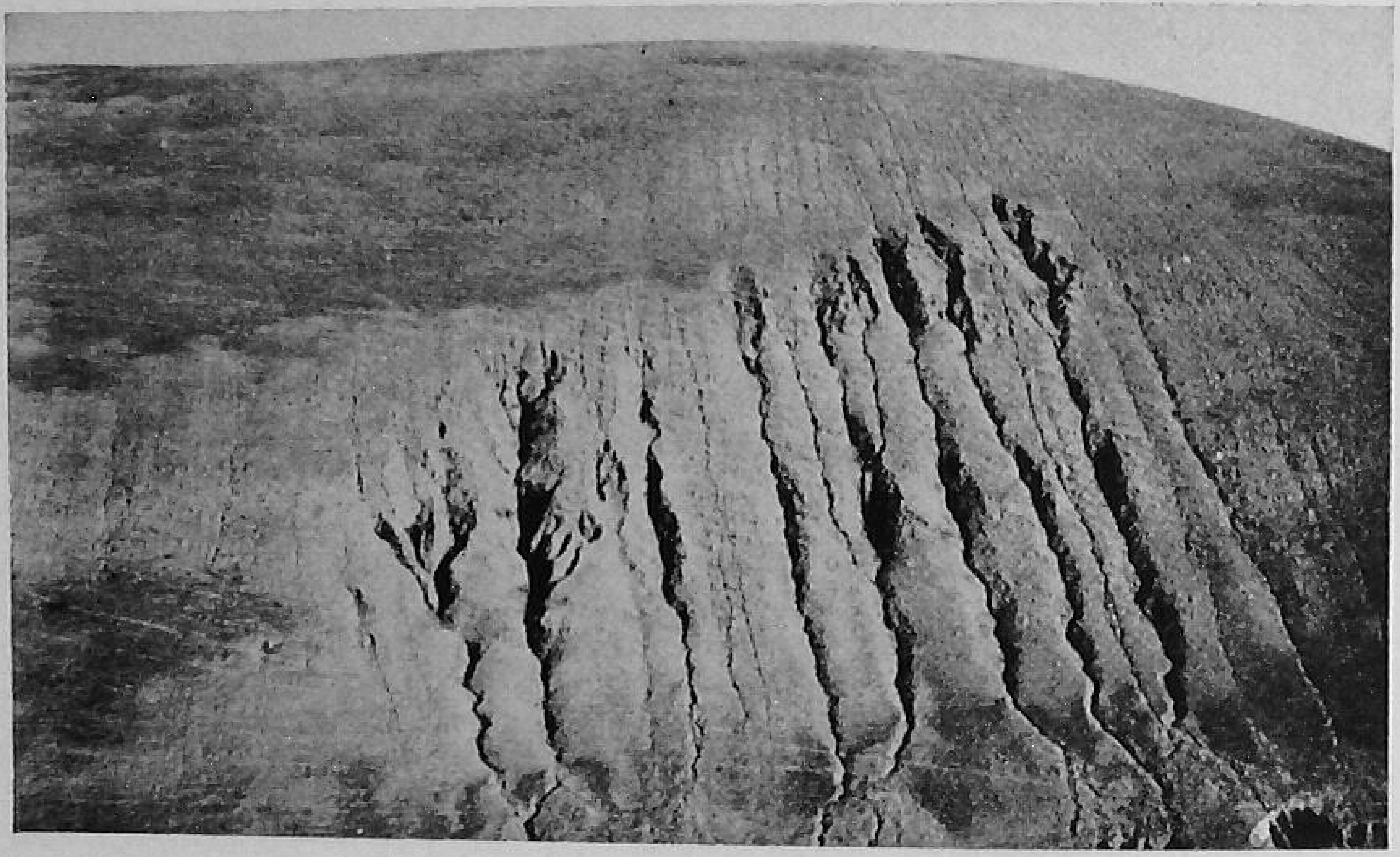


Fig. 8.—Rill, gully, and sheet erosion on steep overgrazed slope, San Joaquin Valley, California. (Photograph by U. S. Forest Service.)

On the basis of census statistics (1940), about 398 million acres are actually in cultivation, including idle or fallow land and land on which crops failed. In addition to this actual cropland, however, over 100 million acres of plowable pasture, woodland, meadow, brush and slash, and unused wet areas could be plowed if absolutely needed and provided the land could be spared from pasture requirements. Even small parts of the Western range, here and there, could be plowed perhaps if eventually needed. Considerable swamp land and overflow strips along streams could be drained and planted. Several million acres could be made productive by irrigation, and here and there patches of forest could be cleared and used if needed.

On the basis of available information, it is roughly estimated that 90 million acres not included in farms by the 1940 census could possibly be cultivated with sufficient development if absolutely needed. This would consist of land of varied quality now in private and in county, state, and Federal holdings (school lands, railroad lands, parks, forests, irrigable lands, etc.). This would bring the total area of plowable land, farm and nonfarm, in continental United States to about 654 million acres, including all land now in cultivation and all that could be brought into cultivation through reasonable drainage, irrigation, and clearing developments.

But because of unfavorable soil or land condition (steepness, stoniness, shallowness, salinity, or susceptibility to erosion or drought), part of this land, although plowable, should be used only for grazing, trees, or wildlife. (Of the 90 million acres of undeveloped, plowable nonfarm land, it is roughly estimated that 40 million acres could perhaps be used eventually with some degree of success for cultivated crops, if needed.)

Of the 564 million acres of plowable land now in farms (cultivated and uncultivated), about 460 million acres represent really good cropland from the standpoint of capability and desirable use. But not all of this 460 million acres of good cropland largely now in farms—the best land that we have in the United States—can be classed as secure. Actually, all of it but about 75 to 100 million acres is subject to erosion if used without protection. The bulk of this best land, therefore, must be safeguarded for all time to come if it is to sustain a permanent agriculture.

Seriousness from Place to Place. Table 1 presents (1) a summarization, by major groups of land, of the estimated approximate extent of erosion in the United States based on degree of seriousness and (2) estimated approximate extent of *plowable* land and *good plowable* land.

Table 1. *a*. Estimated Extent of Erosion Damage in the United States

Condition of Erosion		Area, Acres
Damaged, all types of land (crop-, grazing, etc.):		
Essentially ruined or severely damaged	282,000,000	
Moderately damaged or erosion beginning	775,000,000	
Total area damaged		1,057,000,000
Damaged, cropland (mostly within 150 years):		
Essentially ruined for further cultivation	50,000,000	
Almost as severely damaged	50,000,000	
One-half to all topsoil gone	100,000,000	
Erosion beginning	100,000,000	
Total area cropland damaged	300,000,000	
Not now damaged:		
Land in forest, grassland, swamp, marsh, etc.		702,000,000
Damage not defined:		
Desert, badlands, Western mountain areas, etc.		145,000,000
Total land area		1,904,000,000

b. Estimated Cropland Resources in Farms, United States

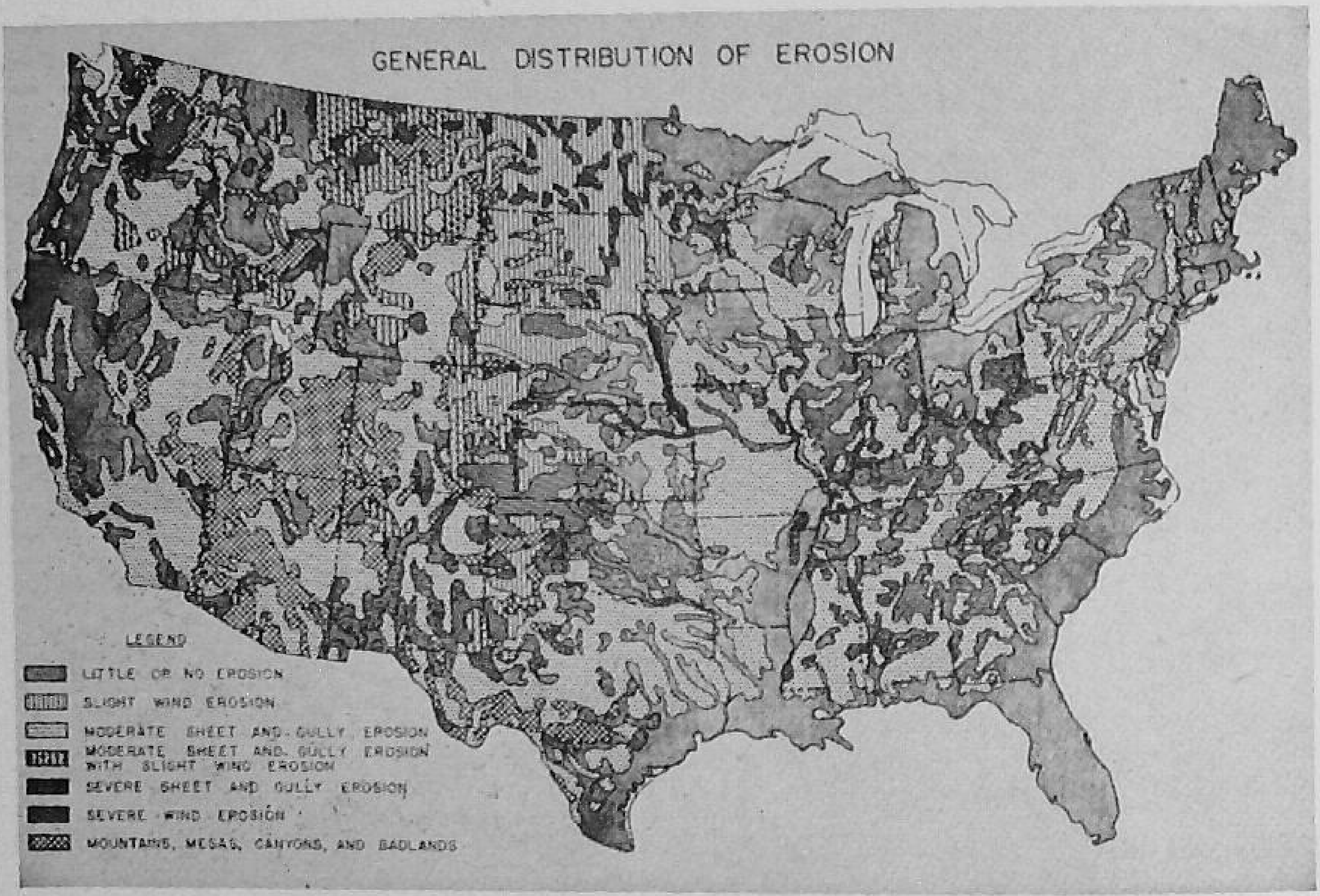
		Area, Acres
Used for crops, harvested and failure, and temporarily idle or fallow (census, 1940)		398,000,000
Of this, not suitable for cultivation		40,000,000
Cultivated land suitable for crops		358,000,000
Uncultivated plowable pasture, meadow, and unused wet land	132,000,000	
Uncultivated plowable woodland, slash, and scrub or brush	34,000,000	
Total uncultivated that could be plowed	166,000,000	
This does not mean that the wise thing to do would be to plow up immediately even the best of all such plowable grassland and woodland, etc., since there is continuing need for great quantities of the beef, milk, cheese, butter, and wood that come from these lands. In an emergency, the part of these uncultivated plowable lands that could be efficiently cultivated without sacrificing too much would probably amount to about		102,000,000
Total good plowable cropland in farms from standpoint of practicability		460,000,000

A small part of the 460 million acres of best plowable land in the United States is probably not included in farms at present.

Only a small portion of the cultivated land of the country is flat enough to be entirely free from soil washing—much less than was supposed as recently as around 1930. The bulk of sloping land in the Corn and Cotton Belts, in the Palouse section of the Pacific Northwest Wheat Belt, in the tobacco areas, in the interior valleys and basins of California and other Western states, and in the potato areas throughout the country may be classed as definitely erodible by water. The rolling grainlands of the humid regions are also subject to impoverishing erosion, although a cover of grain usually is more resistant to erosion than the "row" crops (cultivated crops). Fairly large parts of the vast central plains region (the 250 million acres of the Great Plains area) extending from the Panhandle of Texas and adjacent New Mexico northward through Oklahoma, Kansas, Colorado, and Nebraska across the Dakotas and eastern Montana and Wyoming are only moderately troubled by water erosion, except locally, because of the gentle slope of much of the land and the low supply of rainfall. The greater erosion problem in the Plains is wind erosion, and this is true also of many local areas west of the Plains. Water erosion, nevertheless, is a very serious problem over millions of acres of the Plains country. Wherever Plains land and other similar lands, whether sloping or level, are continuously cultivated, overgrazed, or for any cause left bare of protective cover, they are generally susceptible to blowing in times of protracted drought. The degree of severity ranges all the way from minor disturbances of the surface soil to the major dust storms that sweep across the country, depending on the land and how it is used.

Map 1 shows the general distribution of actual and potential soil erosion in the United States. Here are shown only the more important areas within which erosion is a widespread and serious problem.

Some Examples of Erosion-depleted Land. Of the enormous acreage of seriously eroded land in the United States, certain areas stand out in bold relief. Throughout hundreds of important farming localities, erosion has now progressed so far that the rehabilitation of numerous tracts, both small and large,



Map 1.—Principal areas of erosion in the United States, comprising 25 per cent or more of the land, affected as indicated.

is practically out of the question. These "sore spots" of American agriculture lie scattered across the nation; taken together, they constitute a grim reminder of the power and destructiveness of rain and wind.

The Piedmont Plateau and upper Coastal Plain sections of the Southeastern states comprise one of the oldest agricultural regions in the nation. Cultivation began on some of this land about the middle of the seventeenth century, and erosion has been a problem on much of it from the beginning. As early

as 1685, the first William Byrd of Virginia wrote about a heavy rain on his farm land that washed away tobacco hills "with all the top of the manured land." For 200 years and more, rainwater has gouged away these Piedmont farms, cutting ever deeper into an enormous total area of the land surface. Today, a number of counties of this region contain some of the most severely eroded land within the boundaries of continental United States.

What has happened in Stewart County, Georgia, in the Coastal Plain section, is a striking example of the extremes to which erosion can sometimes progress when land is farmed without proper precautions. Approximately 70,000 acres (one-fourth of the land in this small county) had been essentially ruined by gullying and deep sheet erosion when surveyed in 1913 (Soil Survey of Stewart County, Georgia). Some of the gullies here are probably without counterpart on the North American continent—huge, yawning chasms 100 feet or more in depth (Fig. 9). One of the worst is Providence Cave, which, according to local information, started with the drip from a barn roof about seventy years ago. Already this enormous earth scar is said to have engulfed a schoolhouse and two farm buildings, and much good farm land has toppled into it.

Severe erosion damage, however, is by no means confined to the Southeast. Other agricultural sections have suffered from this earth disease to an almost equal degree. Oklahoma, for example, one of the country's newest agricultural states, has suffered very severely (Fig. 10). The land was thrown open to extensive agricultural settlement at various intervals during the past 50 years. But by 1934, a general survey indicated that more than three-fourths of the entire state had been affected by soil erosion—mainly water erosion in the central and eastern section and wind erosion in the western part. More than 6 million acres had reached an advanced stage of gullying.

The Pacific Northwest, including the states of Washington, Oregon, and Idaho, is another of the nation's youngest farming sections that has fallen prey to progressive erosion. Only within

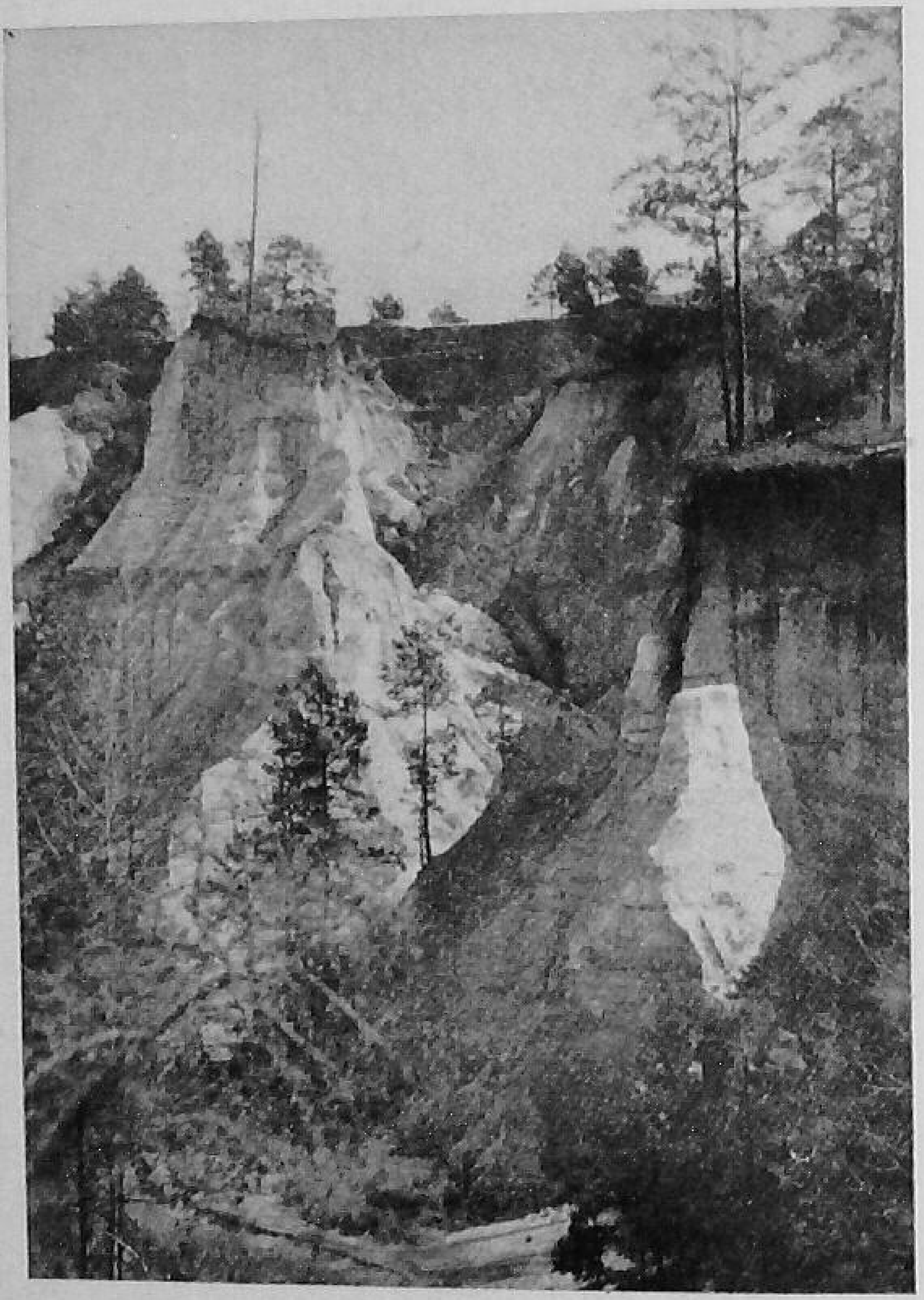


Fig. 9.—Providence Cave; a gully in southwestern Georgia said to have started some 70 years ago. Now more than 100 feet deep.

the past 65 years has agriculture been practiced in these states on any very large scale. But already the ravages of erosion, both by wind and water, have been extensive. According to survey data, about 36 per cent of the farm land in the intermountain zone of the Pacific Northwest is subject to severe soil blowing, and an approximately equal area has lost one-half or

Fig. 10.—A badly eroded farm, redlands of central Oklahoma. Houses kept up but land which cannot be replaced allowed to wash away.

Fig. 11.—Erosion resulting from melting of snow on summer-fallowed land. Palouse region, southeastern Washington. Light-colored elevations in background stripped of highly productive dark soil by erosion, and productivity greatly reduced.

more of its original topsoil as the result of accelerated runoff from cultivated land that a little while ago was perfectly secure under a natural cover of bunch grasses (Fig. 11).

Lying in the heart of the Corn Belt, Indiana has frequently been cited as one of the country's most stable agricultural states.

Fig. 12.—Severe erosion of once highly productive land—ruined for further cultivation. Southeastern Indiana.

Yet surveys show that over 40 per cent of the farming land in Indiana is suffering more or less seriously from erosion. An area of almost 2 million acres has been stripped of more than three-fourths of its original topsoil or is so badly gullied as to be virtually worthless for continued crop production, and sheet erosion is active on an additional 7½ million acres (Fig. 12). From the standpoint of erosion damage, Indiana is still far from being the most severely eroded part of the older farm areas of the East, at least in point of extent, but not many parts of the country have been more completely ruined than several rather

large areas in some of the limestone counties in the southern part of the state. The same can be said of numerous areas in southern Iowa, northern Missouri, southeastern Nebraska, northeastern Kansas, southern Illinois, southwestern Wisconsin, southeastern Ohio, many parts of the bean district of California,

Fig. 13.—Severe erosion of productive valley land induced by overgrazing. New Mexico.

numerous localities in Pennsylvania, Maryland, and New Jersey, and large areas throughout Kentucky, Tennessee, Arkansas, Texas, and northern Louisiana.

Land cutting by erosion has proceeded so far in many parts of New Mexico and Arizona, mainly as the result of overgrazing, that even the details of topography have been altered by gullying. Here, nearly every important valley and tributary valley of localities embracing thousands of square miles are now

incised with one or more gullies, where originally there were none (Fig. 13). Like conditions are found over large sections in Utah, western Colorado, and parts of Idaho, Nevada, and eastern Oregon. Even Maine has local erosion problems of a

Fig. 14.—Erosion of rich potato land cultivated up and down slope. Aroostook County, Maine.

serious nature (Fig. 14), as have the other New England states and New York.

Some of the most spectacular erosion of the country is to be seen in the loessial section of Mississippi and west Tennessee. Here gullying of a peculiar type has gouged large areas to such a state of ruin that there is no chance of getting the land back into condition for cultivation (Fig. 15).

In a single county in southeastern Ohio, an aggregate area of about 100,000 acres of formerly cultivated land has been largely or entirely stripped of topsoil, most of it now producing only

Fig. 15.—Land ruined for further cultivation by erosion. Formerly rich loessial soil. The good soil is gone; the people are gone; even the roads have washed away. Lafayette County, Mississippi.

poverty grass, goldenrod, bushes, and other vegetation of little or no value except that it is helping to check further erosion (unfortunately, after the topsoil has gone downstream).

Questions

1. Why was the public so slow to recognize the erosion problem?
2. What brought about increased interest?
3. How much cropland has been practically ruined by erosion for further cultivation?
4. How much land of all classes has been affected?
5. How much good cropland is left in the United States?
6. How much of the good cropland is subject to erosion?
7. How widely has erosion spread through the nation?
8. Give two or more regional examples of severe effects of erosion.
9. When did the first great dust storm occur?

10. When was the first Soil Conservation Act adopted by the Congress?

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CHAPTER 3

Effects of Erosion

PRESENTING:

Erosion and Farming Operations
Subsoil Farming
Effect of Soil Loss on Yields
Erosion Deposits on Agricultural Land
Erosion Deposits in Reservoirs, Waterways, and Harbors
Effect of Erosion on Floods
Erosion and Water Supplies
Effect of Erosion on the Western Range
Erosion Damage to Highways and Railways
Wind Erosion
Economic and Social Consequences of Erosion
Effect on Tenancy
Effect on Taxes, Purchasing Power, Community
Life, Education, and Health

Erosion and Farming Operations. The ease with which tillage operations can be conducted depends on the smoothness of the ground and the tractability of the soil. Rough, hummocky ground; stiff, unyielding clay soils; deep loose sands; and shallow, stony areas always have been avoided by farmers wherever other land was available.

When a field is cut to pieces by numerous small trenches (gullies) the difficulties in plowing are considerably increased, even though the ground is smoothed off (and the washes forgotten) by the next cultivation (Fig. 16). When deep gullies appear, however, the work of the farmer in that particular field is multiplied. In such advanced stages of erosion, the effects

are not amenable to easy repair, nor can they be forgotten. Usually, such fields are abandoned because of the difficulties of crossing the ravines.

Fig. 16.—Gullies plowed in on steep wheat fields in Palouse region of Washington to facilitate operations of harvesting machinery. Photograph made after the wheat was cut in August.

Subsoil Farming. As every heavy rain washes off a layer of topsoil, the farmer's plow gradually approaches the subsoil. Often the subsoil, when finally exposed, consists of tough, stubborn clay (Fig. 17); loose, droughty, sandy material; unstable, soft "rotten" rock; or worthless hardpan. Not only is subsoil farming an unprofitable venture in most instances; all too often, it is also a backbreaking, expensive, fruitless task.

Exposed subsoil of various types of land, such as the red lateritic soils of Southeastern United States and the Pacific

Coastal region (old soils of high iron content) and some of the better drained lands of the subhumid states, produces quite satisfactorily with good treatment. The red lands usually need manure or fertilizer, and all subsoils are deficient in humus.

Fig. 17.—Erosion-exposed clay subsoil of Shelby loam, sun-baked, cracked, and dry—exceedingly poor. Best stalk of corn in this part of field is that by the hat. It was a good corn year, but this eroded area made no corn, where 40 bushels an acre or more used to be grown without fertilizer before the productive topsoil washed off. Nodaway County, Missouri. (Photograph by author, 1929.)

Subsoils also are usually more difficult to keep in good tilth, and are more erodible and less productive than the topsoil.

Effect of Soil Loss on Yields. Over the past thirty or forty years—up to the middle thirties—the average yield per acre for most of the country's staple crops had been maintained at a fairly even level. In some instances, the per-acre yield had shown a slight increase; in others, a moderate decrease.

When one considers what had been done for the betterment of agriculture, such as improvements in crop varieties, increased use of better farm machinery, and more general use of lime, fertilizers, and crop rotations, the failure of nation-wide yields to increase (until the more recent programs of conservation went into effect) was difficult of explanation to those not familiar with the impoverishing effects of soil erosion. But for the help of agricultural science and the ability to replace worn-out land with good land, such as that brought into cultivation through drainage, irrigation, and new clearings, the average per-acre yield doubtless would have declined even more.

If corn is taken as an example, the average yield for the United States for the 10-year period 1871 to 1880, was 26.4 bushels an acre as against 25.9 bushels for the period 1921 to 1930. And yet, much was done between these periods to increase the yield of corn. When it is considered that corn growing was not extended on any exceedingly large scale into the low-rainfall areas and was not affected by any far-reaching insect or disease scourge during these periods, only one conclusion can be reached: For the nation, erosion during the latter period thwarted much of the stupendous effort that was made to increase the average yield of our crops.

In numerous localities, the yield of corn declined much more than the nation-wide average, even to the extent of necessitating abandonment of many thousands of fields severely impoverished or worn out by erosion—many of them entirely stripped of the more productive topsoil and others rutted with deep erosion channels impassable to farm machinery.

Table 2 shows the per-acre yields of corn and cotton for the decades 1871 to 1880 and 1921 to 1930.

When soil is removed bodily from a field, both available and potential plant food along with temporarily inert mineral material and everything composing the body of the soil is carried away. As erosion progresses and stiff clay of low capacity

TABLE 2. ANNUAL AND AVERAGE ACRE YIELDS OF CORN AND COTTON FOR THE DECADES 1871 TO 1880 AND 1921 TO 1930

Year	Corn,[1] bu. per acre	Cotton,[2] lb. lint per acre	Year	Corn, bu. per acre	Cotton, lb. lint per acre
1871	27.2	159.0	1921	28.4	132.5
1872	29.4	182.3	1922	27.0	148.8
1873	22.9	168.3	1923	28.4	136.4
1874	22.2	157.0	1924	22.1	165.0
1875	27.7	181.2	1925	27.6	173.5
1876	26.7	167.6	1926	25.6	192.9
1877	25.8	170.4	1927	26.6	161.7
1878	26.2	167.5	1928	26.6	163.3
1879	28.2	180.5	1929	25.8	164.2
1880	27.3	190.9	1930	20.5	157.1
Average acre yield.	26.4	172.5	. . . .	25.9	159.5

[1] Compiled from data published in *U. S. Dept. Agr., Agr. Statistics*, 1937, pp. 39–40.

[2] Compiled from statistical data, Cotton Revision, Acreage, Yield and Production, 1866–1935, Bur. Agr. Econ., 1936.

for taking up rainfall is approached by erosion and finally exposed in fields, the ability of the land to supply the moisture necessary for plant growth is generally impaired, the beneficial activity of microscopic organisms lessened, and efficient tillage rendered more difficult. Nearly every important soil type in the United States is made up of a series of soil layers, or horizons, overlying one another. The uppermost layer (the top-

soil) is the most productive. Experiments conducted on a number of important types of farm land throughout the country have shown that yields on the topsoil run anywhere from about $1\frac{1}{2}$ to more than 30 times as high as on similarly treated adjoining areas of exposed subsoil.

Fig. 18.—Highway and adjacent land covered by wind-drifted sand. Road impassable; land less productive. Western Oklahoma.

Erosion Deposits on Agricultural Land. The effects of erosion on crop- and grazing lands are not confined to those fields and pastures which have been stripped of their productive topsoil by water or wind. Material coming first from the topsoil, then from erosion-exposed subsoil, carried in suspension by running water, is frequently dropped on low-lying areas where, because of the flatness of the land, the rate of flow is diminished. Also, wind-assorted sand—the loose residue left after dust storms—when blown from an unprotected field may be spread over adjoining land for many miles around (Fig. 18). It is

the larger, less fertile particles (sand and fine gravel) that usually are dropped or blown over the neighboring agricultural lands; the finer, lighter, and more fertile particles (silt and clay) generally are carried long distances, whether transported by water or wind (the assorting process by water is much like that of wind). Moreover, the subsoil material discharged from gullies is usually not very productive and impoverishes lower slopes and bottomland over which it is laid down by runoff or overflow water. Coarse sand, gravel, and even boulders are often washed from eroding uplands and swept out over productive lowlands.

The damage that has been inflicted on American farm lands by deposits of erosion debris has not been accurately measured, but the aggregate area unfavorably affected, including bottomlands that have been made swampy by increased overflow from streams choked with the products of erosion, probably amounts to around 10 million acres of formerly good, cultivated or cultivable land.

Flood deposits sometimes reach tremendous proportions. The Ohio River flood of January, 1937, for example, laid down 17 million tons of sand in varying depths over 26,000 acres of rich alluvial land between Pittsburgh and Cairo. Hundreds of acres of bottom soil valued at $100 an acre were ruined, at least temporarily, by heavy deposits of loose sand of low productivity (Fig. 19).

In 1929, a flood swept down the Rio Grande that almost destroyed the town of San Marcial, N. M. Measurements showed that approximately 100 million tons of eroded soil material were deposited over the flood plain between the head of water in Elephant Butte Reservoir and the mouth of Puerco River. In some places, sand was laid down to a depth of 7 feet (Fig. 20); in other places, a thick blanket of clay was laid over cultivated fields. Much farm land was ruined, and huge quan-

tities of material were dumped in the great Elephant Butte irrigation reservoir.

Erosion Deposits in Reservoirs, Waterways, and Harbors. Not only is eroded soil a menace to agricultural land; it is

Fig. 19.—Sand deposited over a large area of Ohio River alluvial plain by flood of January, 1937. In 1936 this field produced about 100 bushels of corn an acre and was valued at $100 an acre. It was made practically worthless by the sand.

piling up in immense quantities behind dams, in waterways, and in harbors. In hundreds of American reservoirs, huge deposits of soil material washed in from the uplands are crowding out the water that these costly structures were built to store (Fig. 21). Since it is impracticable to clean out a major reservoir once it is filled with mud, not only is the storage capacity lost, but in the practical sense, the dam site, a valuable resource in itself, is disposed of.

Fig. 20.—Seven feet of sand laid down in the town of San Marcial, N. M., by the 1929 flood in the Rio Grande. Large areas were coverd by these deposits. (Photograph by author.)

Fig. 21.—Reservoir on Dan River filled with the products of erosion. Lynchburg, Va.

Silt deposition (eroded soil material transported by water) is also a troublesome problem along both natural and artificial waterways. Erosion debris is clogging numerous small streams and shoaling the channels of navigable waterways; it is also reducing the carrying capacity of drainage and irrigation canals

Fig. 22.—Drainage ditch, northwestern Mississippi, filled with erosion debris—mainly sand—before the bonds for the establishment of the drainage district were paid off.

(Fig. 22) and ditches. It is forcing many streams from their natural courses, thus causing increased damage to adjacent bottomlands. In many of the country's harbors and along a number of important streamways, navigation is constantly threatened by shoaling, and expensive dredging operations are being necessitated by the accumulation of soil, often carried from fertile uplands hundreds of miles away.

Effect of Erosion on Floods. Every stream throughout the world that is bordered with a strip of alluvium (alluvial soil),

whether a mere ribbon or a vast plain like that of the Mississippi or Nile bottoms, has been subject to overflow for undeterminable time. Alluvium is the product of deposition of silt from overflow water; it is formed in no other way. But the composition of the alluvial material along thousands of streams reveals today a highly significant fact: Alluvium laid down by floods of the preagricultural period of America is generally composed of relatively fine soil particles, and the material is comparatively uniform in texture; on the other hand—and here is the significant fact—the alluvium deposited by more recent floods is ordinarily coarser and much less uniform. The line separating the old alluvium from present-day stream deposits frequently is so sharp that it can be photographed readily (Fig. 23). In other words, the floods that occurred under the virgin-land conditions of early America must have been more like gentle inundations which slowly laid down uniformly fine material; in contrast, the floods of recent years have been more on the order of rushing, tearing torrents, capable of transporting heavier, coarser particles to be deposited alternately with the fine materials laid down from moderate overflows from intervening floods.

Within the past forty years or so, floods in nearly every section of the country seem to have increased in frequency, volume, and velocity. For example, in early 1937, a deluge swept the whole Ohio Valley, breaking records for height of flow (flood crests) at many points. The preceding spring, record-breaking floods struck with appalling destructiveness over much of the northeastern section of the country, leaving difficult and costly problems to be solved, not only immediately along channel ways but out in the fields and pastures from which so much of the floodwaters come. Nearly every year, unprecedented floods are now being recorded along various streams of the country. In 1943, the Arkansas broke all records for height

at Fort Smith, Ark.; and in 1944 and 1945, still other new flood-height records were set up on other streams.

Soil erosion is caused by accelerated runoff of rainfall (and

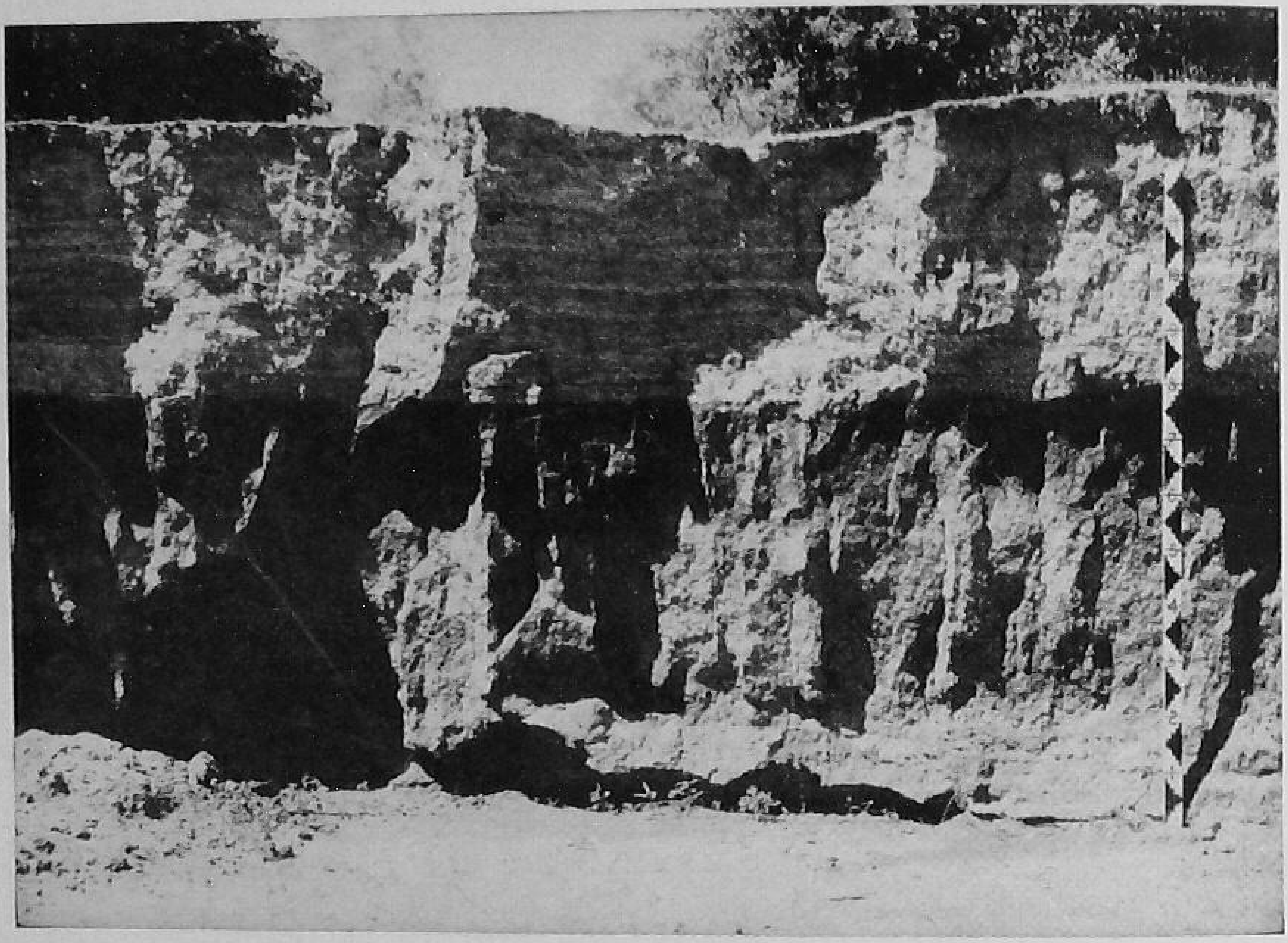

Fig. 23.—Profile on the watershed of a tributary of Coon Creek, Wis. Since the beginning of farming about 70 years ago, 5 feet of soil material has washed down over the alluvial bottoms. The time required to deposit the 8 feet of material now buried below the dark center line, which marks the surface of the soil at the time of settlement, may have exceeded 10,000 years. The old alluvium of the preagricultural stage has the uniform character of deposits laid down by moderate floodwaters. The new alluvium has the diverse character of deposits laid down by violent floodwaters.

melted snow) following removal of the vegetative cover; runoff, in turn, is speeded up as absorptive topsoil is removed to expose relatively unabsorptive clay subsoil over which water moves with increased speed, as from a tin roof, in the direction of stream channels. Millions of gullies form new tributaries to natural drainage ways; they concentrate runoff water and

discharge it into streams at maximum speed. Other new tributaries are roadside ditches and drainage canals. Even the hundreds of millions of furrows between crop rows that unfortunately run up and down slopes are gutters that carry rainwater rapidly off the land.

The natural drainage system of the country—the branching network of rivers and their tributaries—was carved out by nature to dispose of runoff that formerly flowed gently or trickled down from naturally vegetated slopes across land that was spongy and absorptive. At present, these natural channels are being called on, over short periods, to carry enormously increased volumes of water rushing in from the new man-caused tributaries and from slopes stripped of absorptive topsoil through man's use of the land. To make matters worse, some of these channels are now in no condition to take care of even a normal burden of floodwater. Erosion debris washed from upland fields and pastures has accumulated in numerous stream channels, reducing their carrying capacity and helping to raise the crests of floods.

In the light of these facts, it becomes easier to understand why, from time to time, levees are being built higher and higher and dams larger and larger and at more and more points along our waterways. This may be only a partial explanation; in some watersheds, other factors obviously are involved, such as multiple-purpose reservoirs for flood control, irrigation storage, power, and city water supply.

Frozen ground of bared fields and water-soaked condition of the ground at the time of heavy downpours have been important contributing factors in many floods; but widespread soil erosion resulting from unwise farming practices is among the major influences lying behind the nation's growing flood problem.

Erosion and Water Supplies. Although the more humid regions and to a considerable extent the dry-land areas also have been plagued in recent years with increasingly destructive floods, the drier sections of the country have been the frequent victims of that contrasting phenomenon known as *drought.*

Man is powerless to prevent periods of low rainfall, but often he is able to reduce the effects of drought by making the utmost working use of all the rain that falls on the land.

With practical measures, such as contouring, terracing, subsoiling, strip cropping, and surface mulching, much of the water that falls on the land—sometimes all of it—can be stored in the soil (absorbed by the soil) for subsequent crop use. On grazing lands, the same result is effected by leaving a part of the forage growth ungrazed. Not only do these measures increase the available supply of stored soil moisture, but they soften the soil and make it easier for plant roots to bore through in search of conserved moisture.

Soil erosion, by sealing over the ground surface and thus clogging the entrances into the soil, also causes less water to filter down into the substrata to replenish the *underground water supply,* so valuable for pumping.

It has been reported that during the drought of 1934, the water table dropped in areas of the Great Plains as much as 20 feet. The larger part of this loss probably was due directly to rainfall shortage, but some of it seems to have been the result, directly or indirectly, of accelerated soil erosion. In various parts of the country, gullies have cut so deeply into the pervious materials of valleys, thus opening new outlets, as to drain out the accumulated water of the substrata. Such release and wastage of underground water frequently damages the vegetation and sometimes even kills trees. Drainage works also have contributed locally to subsidence of the water table. And, of course,

pumping for industrial use, for irrigation, and for city-water use has lowered the level of underground water.

Over large parts of the country, water may be considered the beginning and end of agriculture. Throughout the Great Plains and over wide areas in the West and Southwest, the key to successful farming is largely an adequate supply of water. Already erosion has made sharp inroads into that supply by increasing wastage through runoff; in the future, the effect may be even greater. If erosion caused no other type of damage, this alone would justify a program of prevention and control.

Effect of Erosion on the Western Range. Perhaps nowhere have the harmful effects of erosion on water supplies and vegetation been more acutely felt than on the Western ranges. This vast expanse of territory, lying between the eastern border of the Great Plains and a comparatively narrow strip of humid country fronting the Pacific Ocean, comprises about 40 per cent of the country's total land area. In early days, it was primarily a grass country, where the native stands in many localities grew tall and lush. It is still a grass country; but over wide areas, the original cover has been crowded out by less desirable plants or has disappeared completely (Figs. 24 and 25). Studies and surveys show that fully half the range country is now suffering a serious depletion of forage plants after only a few decades of grazing.

On the Western range, soil erosion and declining vegetative cover are now complementary processes, the one speeding up the other in a costly cycle of vanishing resources. Overgrazing has been a problem on the ranges of the Western states since the days, more than a generation ago, when cattlemen and sheepmen fought for exclusive use of the grass and water holes. Today that vast range, once capable of supporting 22 million animal units, has an estimated present carrying capacity of only

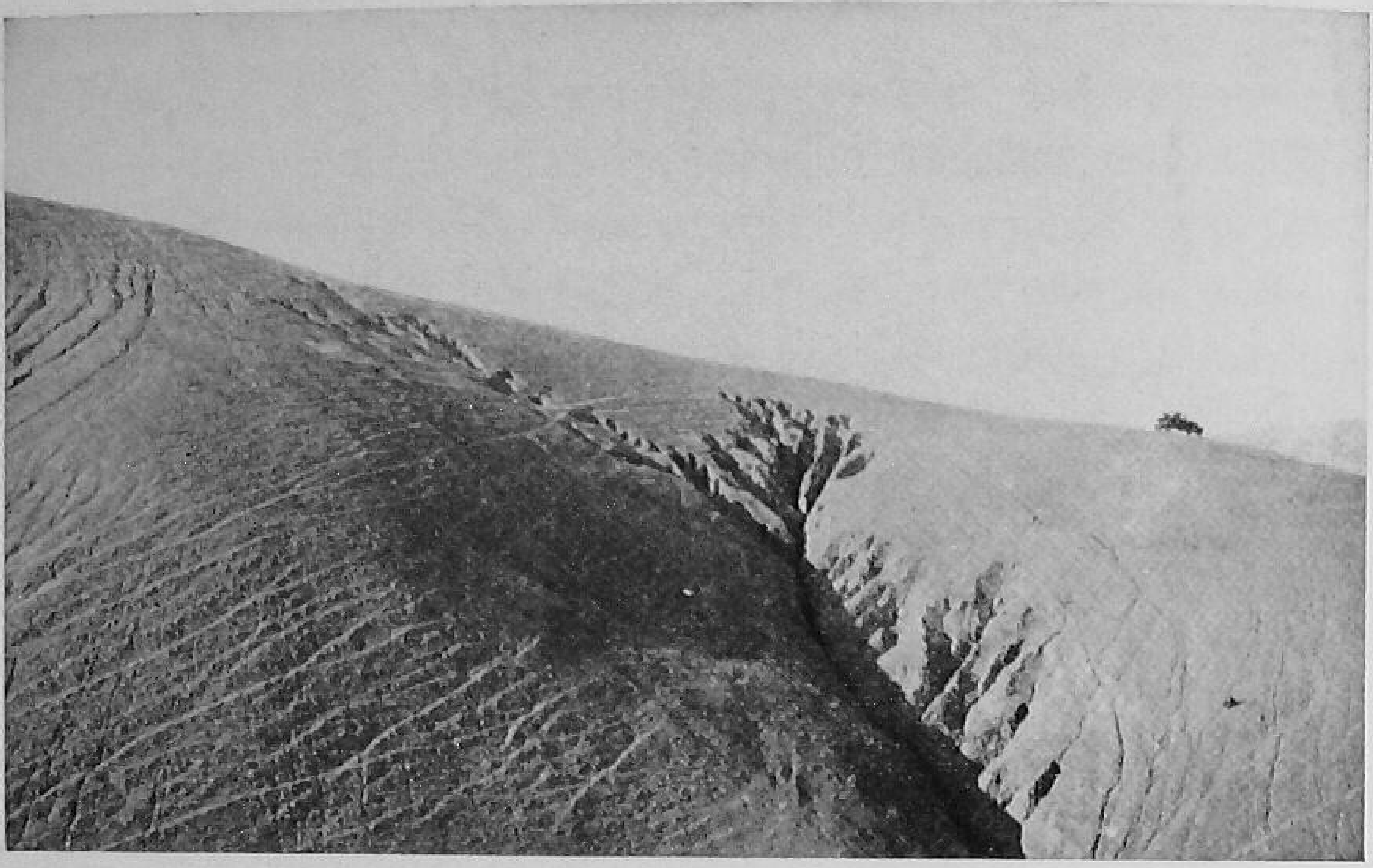

Fig. 24.—Erosion on overgrazed and heavily trailed sheep range in the San Joaquin Valley, California. (Photograph by U. S. Forest Service.)

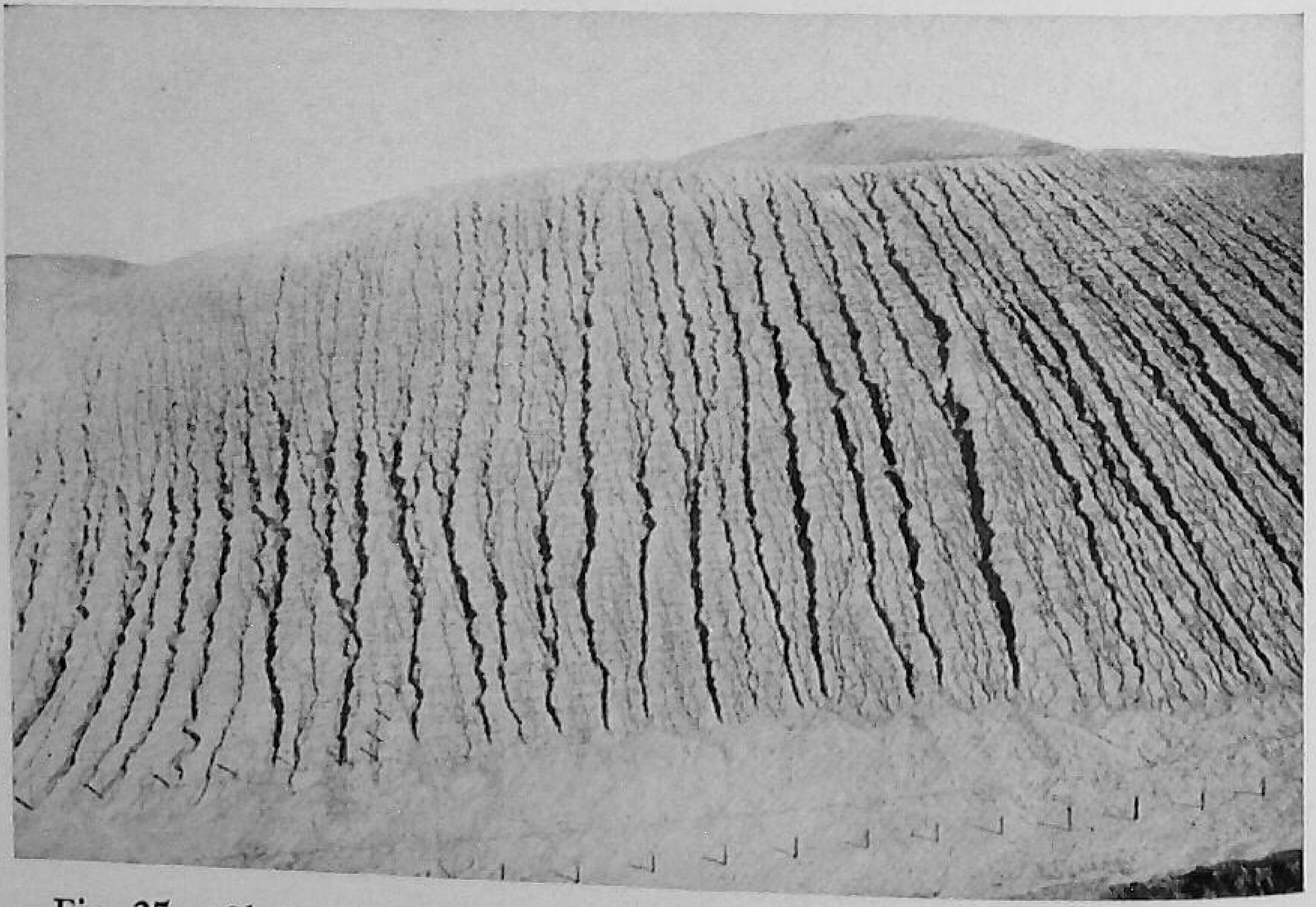

Fig. 25.—Close-up of one of the hundreds of denuded and gullied slopes on privately owned, overgrazed sheep range near Monolith, Calif. (Photograph by U. S. Forest Service.)

about 11 or 12 million units. Yet the area recently has carried much more than this capacity (Senate Document, "The Western Range," 74th Cong., 2nd Session, pp. 10 and 69).

Well-meaning people sometimes furiously deny the bad effects of overgrazing, but the findings of range surveys, made mostly by trained and experienced local people—specialists in appraising the grazing value of ranges—cannot be obliterated by anything short of improved grazing practices. Besides, changes in grazing methods to bring use into better adjustment with carrying capacity usually make it possible, within reasonable time, to run even more animals per unit of land.

Erosion Damage to Highways and Railways. One of the most remarkable achievements of the United States has been the creation of an intricate network of transportation facilities: highways, secondary roads, and railway systems stretching across the country and reaching into nearly every town and hamlet. Yet millions of miles of these costly structures are faced with the hazards of erosion. Highway and railroad embankments frequently have been undermined or washed out by the cutting of uncontrolled water. Along many thousands of miles, both the roadway itself and those who use the roads are menaced by roadside ditches as they cut wider and deeper (with the erosion produced both by direct rainfall and by run-off from adjoining lands). The full cost of erosion damage to American transportation systems is not definitely known. A study of the problem in a typical county (Vernon County, Wisconsin) shows that erosion and flood damage are sometimes responsible for as much as 40 per cent of the annual cost of highway maintenance. Estimates from local authorities indicate an erosion damage to the highway system of Texas, not including repairs to county roads, amounting to $1,566,540 for an 8-month period beginning in September, 1935.

Wind Erosion. In spite of their spectacular nature, dust storms probably have not represented the most damaging form of wind erosion. Sand and finer soil material, moving ahead of wind near the ground, cover range and cropland, smother plant life, and eliminate, at least temporarily, whatever chances there may have been for a harvest or a cover of grass. Often the abrasive force of these wind-driven soil particles is so great as to shear off growing plants just above the ground. In many instances, the shifting, blowing soil has covered highways, banked against buildings, and formed troublesome fence-line drifts and sand dunes that menace adjoining farm lands.

Surveys indicate that the productivity of about 10 million acres has been essentially depleted by wind erosion alone and that a very much larger area has been damaged in varying degrees.

To the land, wind erosion has become a deadly force; to the people living in sections of the country subjected to severe wind erosion, it has become both an economic and a social menace. Uncontrolled, it impoverishes or destroys the source of their major industries—grazing and agriculture. In the more acutely affected localities, it appears to cause, at least temporarily, an increase of pulmonary troubles among human beings, a condition sometimes referred to as "dust pneumonia." In addition, it blankets homes, offices, and stores with dust, covers farm machinery and buildings with sand, soils goods on the shelves, endangers the lives of motorists, and increases the wear on automobiles and farm machinery.

Damage to land and plant life by wind erosion is not restricted to arid or semiarid areas but extends to every state. The effects outside low-rainfall sections are local, however, and confined principally to loose, sandy land.

Economic and Social Consequences of Erosion. In a social and economic as well as a physical sense, the impact of erosion,

whether by wind or water, on agriculture has been far-reaching and profound.

It is practically axiomatic that a process that destroys the essential productivity of land can exercise only an adverse effect on those who depend on the soil. Erosion is such a process, perhaps the most vicious. Other factors being equal, its adverse effect on agriculture and agricultural people is brought about through the progressive deterioration of productive land and consequent lowered farm returns. It frequently leads eventually to discouragement, debt, bankruptcy, farm abandonment, rural migration, disruption of the tax base, general community disintegration, and similar dislocations of an economic and social nature.

Temporarily, the ill effects of soil erosion may be totally or partially offset by other factors of a physical or economic nature. The application of manure and fertilizers, for example, may serve for a time to extend the crop-productive life of land against the inroads of erosion; or high prices may compensate, temporarily, for high costs of production on land depleted by erosion. In the long run, however, uncontrolled erosion eventually makes it uneconomic and often physically impossible to produce from the land, regardless of prices. Crops cannot be grown on sterile clay, bedrock, or fields riddled by impassable gullies.

In some instances, entire communities have been abandoned as the result of serious soil depletion. In a nation as youthful as the United States, any number of communities, no matter how few, abandoned either directly or indirectly as a result of soil erosion is too many. Yet the inroads of erosion on the soil wealth of the country have been so rapid within the past few years that many rural communities are face to face with land bankruptcy and abandonment, with countless areas—farms and parts of farms—already worn-out and retired from cultivation.

Experience has shown that soil exploitation and its progeny soil erosion are not easily halted once an advanced stage has been reached. As the productivity of the land is depleted, farms must be used harder and harder to maintain production. For example, the farmer, pressed for income, may be forced to cultivate erosion-exposed stubborn clay more intensively or to extend cultivation to areas that hitherto he had considered unfit for crop use. Inevitably, the fallacy of this procedure is proved, but the proof helps neither the land nor the unfortunate farmer.

Effect on Tenancy. Tenancy may be traced in many instances to soil impoverishment. The most recent survey shows that more than 42 per cent of the farm operators of the United States are tenants. More than one-fourth of all persons gainfully employed in agriculture are paid farm laborers, and fewer than half of the farmers of the nation own the land that they till. In 1880, according to statistical records, one out of every four farmers was a tenant. Today more than two out of every five are tenants. Furthermore, the equity in the land of many so-called owners sometimes drops so low, because of unfavorable economic conditions, that it scarcely merits the name of ownership—at least this was the state of affairs until the very recent upturn in farmer income.

The average American tenant farmer was moving every three or four years before the Second World War; and in many sections of the country, 1-year leases were running as high as 50 per cent. Brief occupancy of a farm by tenants has encouraged mining of the soil and paved the way for serious erosion. To the average short-lease tenant, the knowledge that he will soon move to another farm discourages care for the land that he is currently farming. Without the incentive and pride of ownership or the advantage of a long lease, he often allows the soil to wash or blow away and the buildings to fall into disrepair.

Once, tenancy in the United States was a sound system of land tenure. It was considered a step up the ladder from farm laborer to farm owner. The position of the tenant farmer was completely consistent with American tradition. This century, however, has seen tenancy become more and more the end rather than the beginning of farm ownership.

Effect on Taxes, Purchasing Power, Community Life, Education, and Health. As land declines in productivity and value, the farmer can pay less taxes; it becomes necessary to revalue his property downward for tax purposes. In this, the community feels another effect of erosion, for the almost inevitable result of lowered taxes on impoverished farms is a higher taxing rate on land still able to pay.

Impoverished and gullied farms are not promising markets for farm machinery, electricity, or the many other industrial products normally needed by the rural population. Beset by taxes, mortgages, credit payments, and declining soil productivity, the farmer cannot be the ally of urban industries in maintaining a healthy business situation. Moreover, under the circumstances, he is virtually forbidden to take a normal, active part in local community life. The farm that is incapable of giving the family a living income provides no incentive for social betterment and no basis for an adequate diet. On the contrary, it is likely to mean ill health, early termination of education for the children, preclusion of church and club activities, and prohibition of entertainment and intellectual luxuries for the adults.

As the area of arable land on a farm dwindles because of erosion, the operator may be forced to curtail his agricultural activities or seek additional land by purchase or rental. Usually he can increase or maintain production output by better husbandry on his better acres; this offers far more opportunity than is generally supposed. But the difficulties are not always

so simple. Where a farm is critically short of good or fairly good soil, land of reasonable productivity may not be available for purchase or renting in the community, or there may be neither funds nor credit for an outlet in this direction. In this way and others, uncontrolled erosion stalemates land users with debt, forces them to migrate or enter another business, or leaves them stranded on wasted land as submarginal patch farmers or public dependents.

Under conditions such as those existing in parts of the Great Plains, certain types of farming may not be adaptable to the soil or climate. Erosion may take too heavy a toll, for example, where wheat is the main crop. The only practical remedy may be to return the land to grass and for the farmer to take up the livestock business. Frequently, this will require a larger area of land. If additional land cannot be obtained by purchase or lease, it may be better in the long run for the farmer to sell or lease his holdings and seek a livelihood elsewhere.

To summarize the effects of soil erosion, it can be said that the process, if uncontrolled, impoverishes not only the land but those who live on and by the land as well as communities and urban areas dependent in part or entirely on the welfare of the farmer.

Questions

1. Give example of the effect of erosion on farm operations.
2. What is subsoil farming?
3. How does erosion influence yields?
4. How does erosion affect stream bottoms?
5. What are the consequences of reservoir sedimentation other than loss of storage capacity?
6. How does deposition of erosion debris affect floods?
7. How do stream deposits from eroding cultivated watersheds compare with those from virgin watersheds? What do the comparisons indicate?

8. How do man's activities increase flood hazards?
9. What is the effect of accelerated erosion on flood heights? Give example.
10. How does erosion affect drought? Underground water supplies?
11. What are the principal effects of overgrazing?
12. Is the present capacity of the Western range as great as it formerly was?
13. How does wind erosion affect farm land? Roads? Machinery? People?
14. How widespread is wind erosion?
15. How can erosion affect the tax base?
16. How do economic factors affect erosion?
17. Name two or more social effects of erosion.

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CHAPTER 4

How Erosion Takes Place

PRESENTING:

Erosion by Water
- **Sheet Erosion**
- **Rill Erosion**
- **Gully Erosion**

Assorting Effect of Water Erosion
Erosion by Wind
Dust Storms

Water and wind are the active forces of soil erosion. They differ in the nature of their action but are similar in that both remove soil from the surface of the land. The transporting efficiency of these agencies is greatly increased with increase in velocity. Both present major problems in land protection, and both call for similar methods of control, the basic essential of which is to reduce the erosive effect by slowing the rate of runoff or the velocity of the wind with obstructions to their progress. A fundamental difference is that slope is essential to erosion by water, whereas it has no important effect on erosion by wind.

Erosion by Water. Water erosion is the movement of soil by rainwater, including melted snow, running rapidly over exposed land surfaces. Its rate of progress is dependent on such factors as slope, soil, density of vegetative cover, and amount and intensity of rainfall. Soil erosion is intensified by improper methods of cultivation, overgrazing, burning, and the activities

of rodents. The principal types of water erosion are sheet erosion and gully erosion.

Sheet Erosion. Sheet washing is the more or less even removal of soil in thin layers, one at a time, from an entire field or other body of sloping land. It is the least conspicuous but

Fig. 26.—Sheet erosion has removed all dark soil in this Kansas field, down to light-colored, limy subsoil. The process has been accentuated by downhill cultivation. Yields severely reduced—from around 40 bushels of corn an acre to about 10 bushels an acre.

the most extensive and insidious type of erosion. Some *grooving* (or rilling) of the surface commonly goes on in connection with sheet washing, but often there are no outstanding surface markings. Frequently, the change takes place so slowly that it seems to cause the land to turn light colored (Fig. 26) as the removal of dark-hued topsoil exposes relatively light-colored subsurface material.

Unprotected land varies widely in its susceptibility to sheet washing, the differences depending principally on slope, cli-

mate, and the character of the soil. Steep and moderately steep lands and those subjected to heavy or intense rains are likely to be the most troublesome areas. Where shallow surface soil overlies dense clay subsoil or other impervious sublayers, the land is especially subject to this form of water erosion. Fine-grained soil of flourlike nature (silt loams), fragile sandy soil, and all soils deficient in organic matter are also exceptionally vulnerable.

Actually, sheet erosion takes place to some extent wherever water flows across unprotected sloping land, as shown by the never failing muddied condition of the water. Similarly, nearly all bare areas are subject to wind erosion when dry, particularly where the soil is loose.

Farmers often fail to notice the effects of sheet washing until unproductive spots of subsoil or bedrock appear in their fields. And often they accept these changes in the land as a part of the natural order of things. Figure 27 illustrates how sheet erosion moves soil from unprotected areas. As shown here, the protection afforded by a single gravel allowed columns of soil several inches high to be formed through the simple process of cutting away the surrounding uncovered, unprotected soil by running water. (Such effects can be duplicated by inserting a bottle cap in sandy soil. It will be found that with such protection of the surface, even on moderate slopes, the surrounding soil is whittled away by the rains at a surprising rate.)

When conditions are such that muddied rainwater is absorbed by the ground, fine particles are carried with it down into the small openings that penetrate the soil like a sieve. By a process of straining out, these particles plug the openings into the soil, thus sealing the surface against further free entrance of water and thereby causing more of the rainfall to flow off the land.

When raindrops strike the soil with considerable force, the larger ones disturb the immediate surface, especially where the soil is loose. Disturbance may be either by compaction or by a geyser-like loosening of the material (Fig. 28), depending

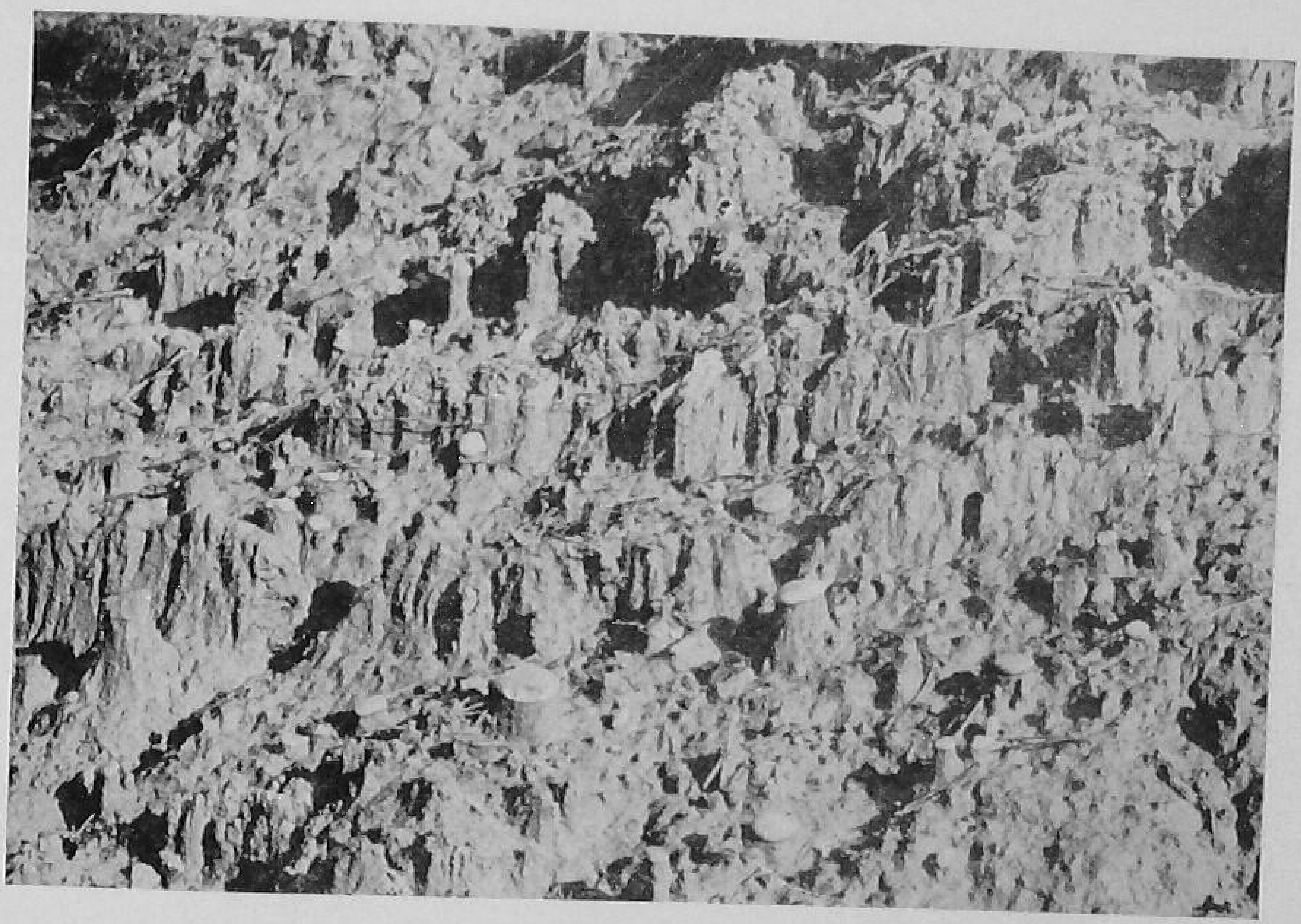

Fig. 27.—Pedestals one-sixth natural size formed by removal of surrounding soil material (sandy loam) through sheet erosion. Tops protected by gravel. Beltsville, Md.

on the condition of the soil. With continuing rain, clods and lumps of soil (soil aggregates) are broken down and a pasty mass is formed. This pasty layer at the surface resists penetration by rainwater and favors rapid runoff, just as in the case of the sealed surface described above.

Frequently, this thin layer, or sealing, is so impervious that the soil at a depth of an inch or two will be dry, even with continued rain. But as rain proceeds, the abrasive force of the increased runoff results in cutting, which after a time wears

through the skinlike layer and starts trenching or rilling. Soil sealed over during rains, especially where not cut by rills (diminutive gullies), often hardens (crusts) on drying, frequently to such degree that even where the material beneath

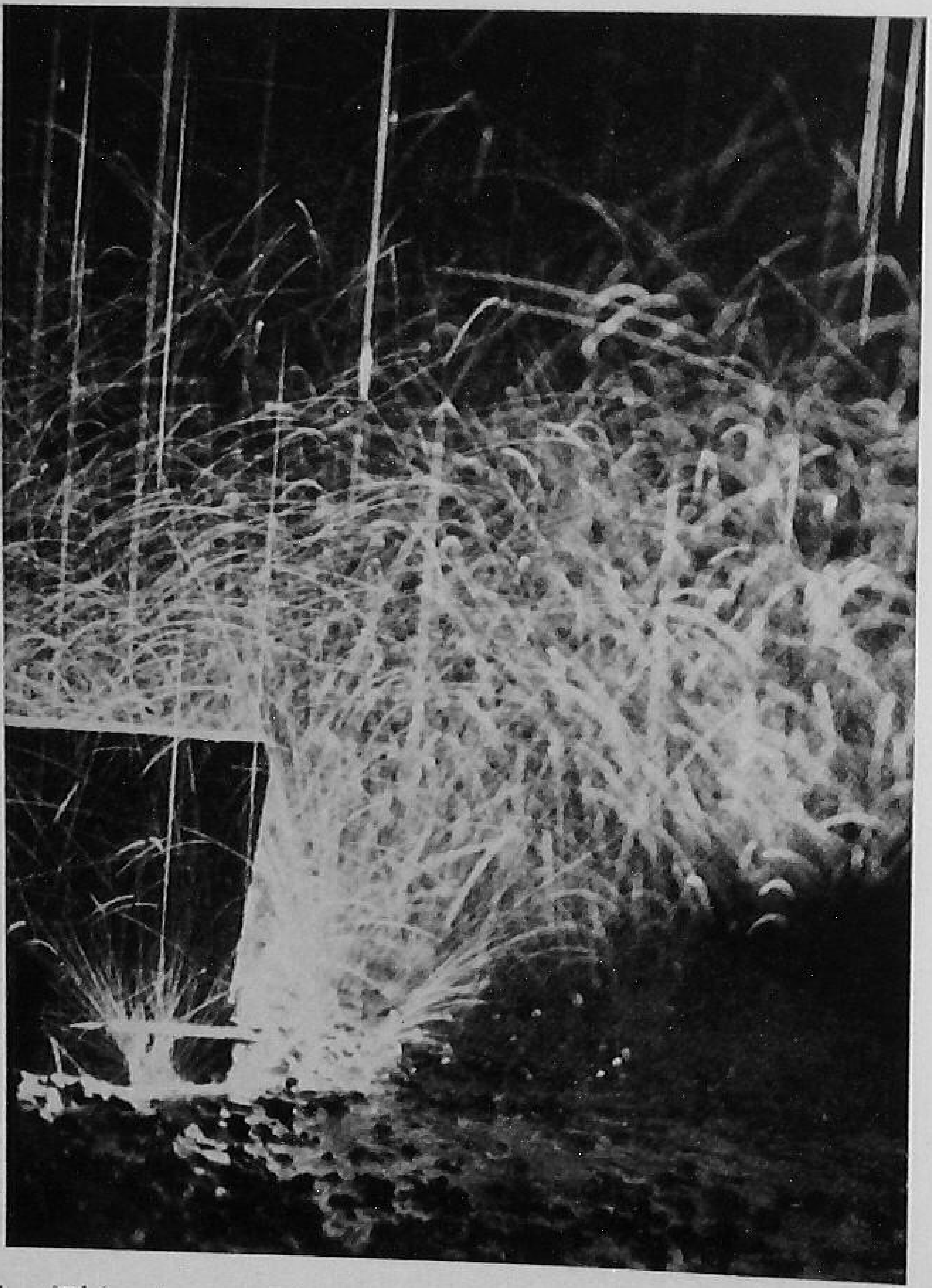

Fig. 28.—This photograph represents 1/25 of 1 second of rainfall action. The straight-line streaks are falling raindrops; the curved-line pyrotechniques are not tracer bullets or shell fragments but splashes of mud thrown into the air by the explosion-like splatter resulting from drops of water falling into water-softened soil. (The inset is a "splashboard" that catches a sample of the soil-carrying splash.)

is soft or loose, sprouting seeds are unable to push up through the crustal layer.

Rill erosion is more apparent than ordinary sheet washing (Fig. 29) but almost as often neglected. The small incisions are easily plowed over and forgotten. With respect to extent of damage, however, this form of soil washing is about as serious as sheet washing. Ordinarily, it is considered as an advanced stage of sheet erosion.

The sudden melting of snow, such as takes place in the region of the Palouse wheat section (southeastern Washington and adjacent parts of Idaho and Oregon) under the impact of warm winds from the Pacific (chinooks), often produces severe rill erosion on these very silty soils. Frequently, the eroded soil is deposited on lower lying accumulations of snow to form peculiar patterns (Fig. 30).

Gully Erosion. This form of erosion takes place where concentrated runoff from a slope is sufficient in volume and velocity to cut deep trenches (gullies) or where concentrated water continues cutting the same groove, such as a rill, long enough to form such incisions. Gullies often have their beginning in slight depressions in fields or just below fields where runoff water normally concentrates. They also develop in ruts left by the wheels of farm machinery, in the trails of livestock, and along furrows between crop rows running up and down the slope.

Ordinarily, gullies carry water only during or immediately after rains or following the melting of snow. They usually cannot be obliterated by normal tillage; most of them cannot be crossed by farm machinery; and some are huge chasms 50 to 100 feet deep or deeper and large enough to engulf enormous buildings. For practical purposes a field gully may be defined as a newly eroded channel at least about 18 inches wide and

Fig. 29.—Rill erosion, crisscross pattern. Ohio.

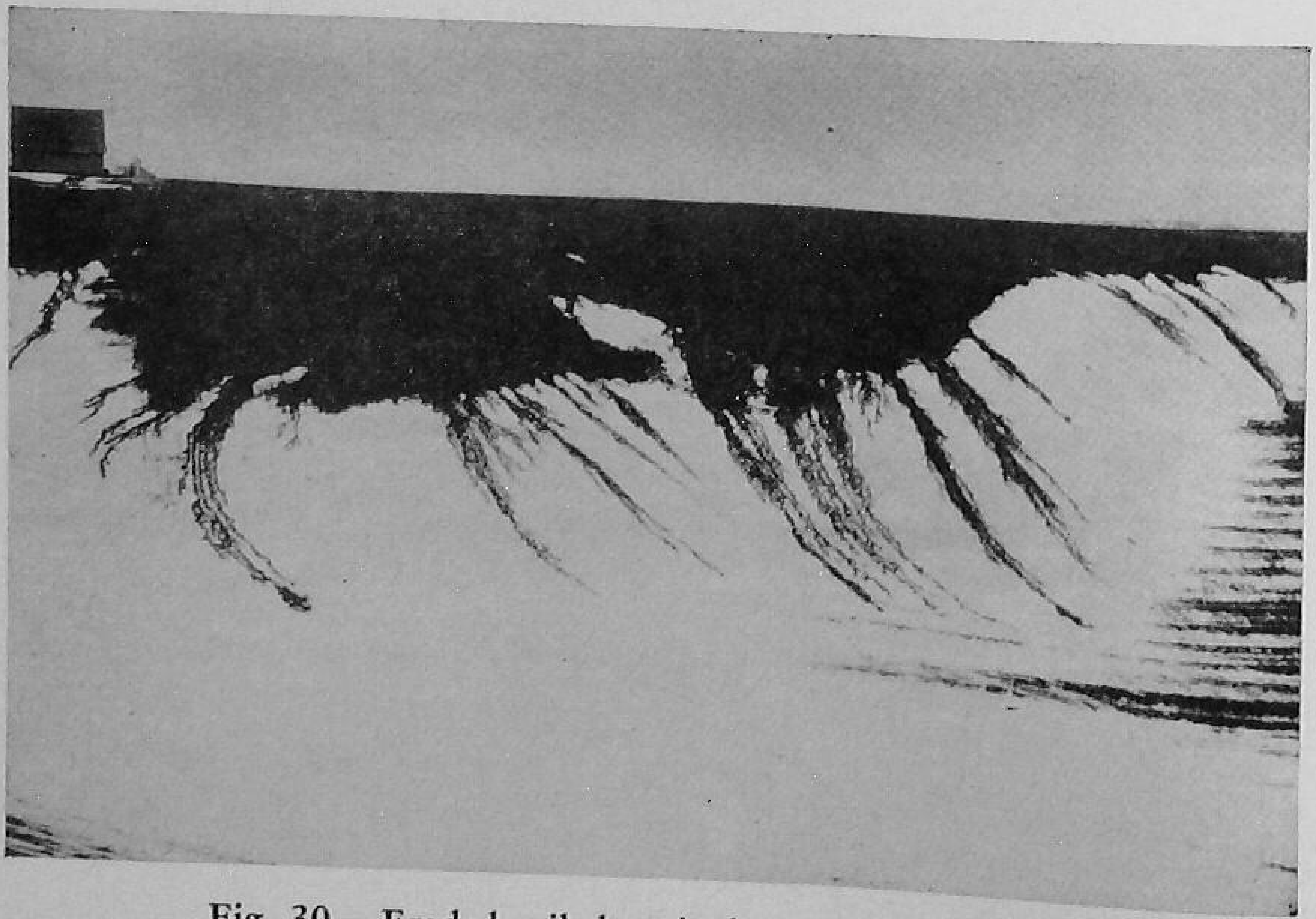

Fig. 30.—Eroded soil deposited over snow. Washington.

10 or 12 inches deep. A woodland gully is usually defined as a newly eroded channel deep enough to expose the main lateral roots of large trees.

There are two principal kinds of gullies: those which have sloping sides with narrow, V-shaped bottoms (Fig. 31) and

Fig. 31—Gullies of V shape on limestone soil. Northwestern Georgia.

those which have straight sides with broad bottoms (Fig. 32). The latter are somewhat U-shaped and generally are less winding than the narrow-bottomed type. The *V-shaped gully* may be considered the normal type of gully trenching, except in soils with soft, easily cut substrata—here the U-shaped type is common.

From the standpoint of seriousness to farmers and ranchmen, depth and rate of extension and especially tendency to branch are the most serious aspects of uncontrolled gullies. By these

standards as well as difficulties of control, the broad-bottomed gully is the most formidable.

But all gullies are serious. Usually their appearance in a field or pasture or on the range means that the land has been over-

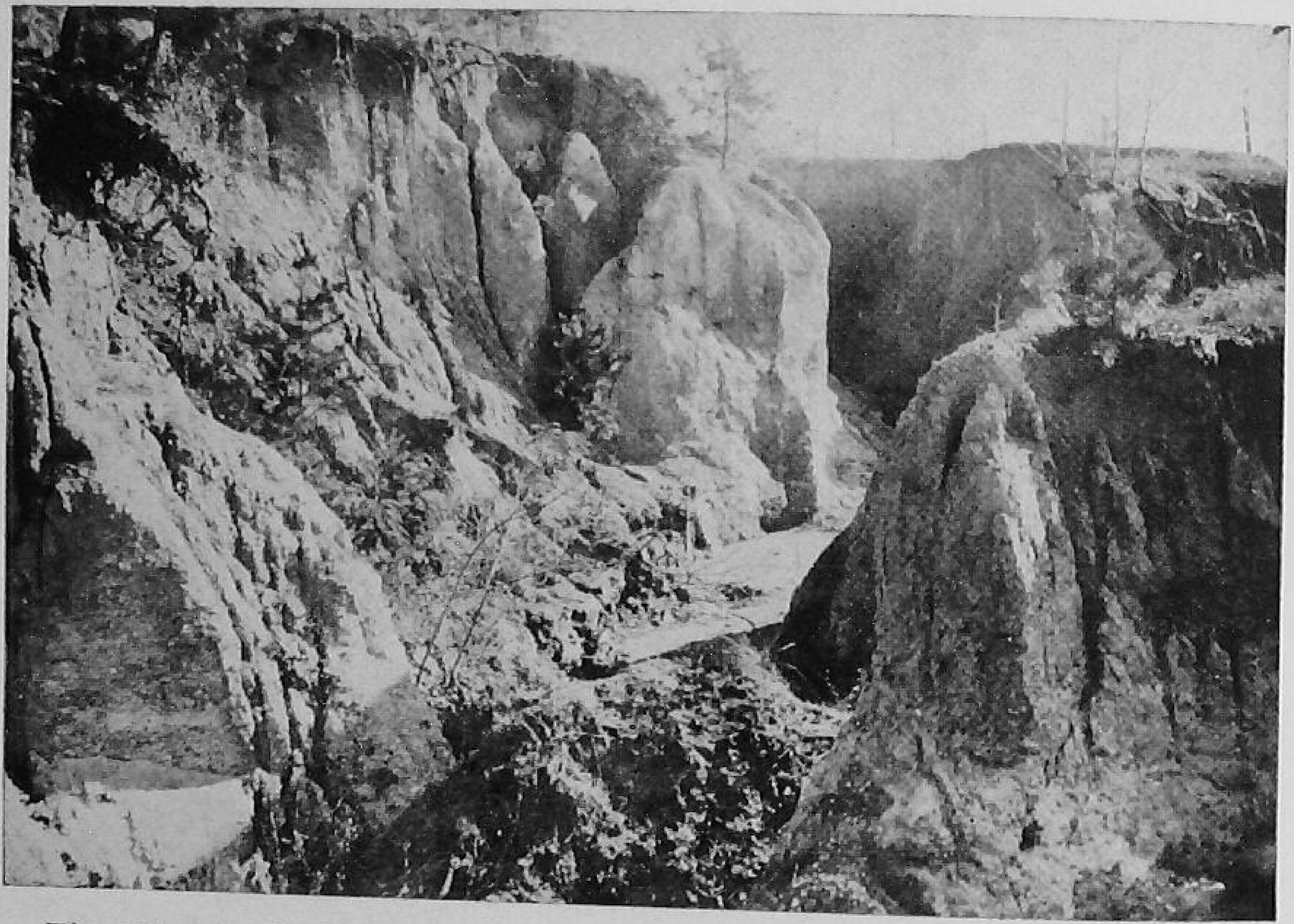

Fig. 32.—South Carolina Piedmont gully which began as V-shaped ravine. The change to U shape, with vertical walls, was caused by undercutting of soft, decomposed granitic rock after the initial gully had cut down into this unstable substratum.

used or abused. Moreover, the beginning of a gully frequently means that the land that it cuts is entering a stage of decline often referred to as worn out. Actually, when land begins to gully at frequent intervals, it usually has reached the condition of old age if not the beginning of the death stage.

Gullied land, generally, is not just in a gullied condition; such land usually has suffered seriously from sheet washing also—along the edges or all the way across from one gulch to

another. Therefore, when gullies appear, the farmer or ranchman should quickly take measures to do two things: (1) treat the cause of the gullying and (2) treat the gully itself with control measures. (Methods of gully treatment are given in Chap. 14.)

The reason why broad-bottomed gullies (U-shaped type) usually are the more serious is that the soft, unstable materials commonly found in their lower depths (such as sand, loose gravel, or soft "rotten" rock) are easily incised and cut out by floodwaters. This ready cutting near the bottom (undercutting) causes the banks to cave off from above, often splitting off in great vertical blocks, thus favoring rapid expansion—and destruction of the land. When the caved-in material is washed out of the gully, the trench is left with more or less straight walls and a bottom width equal that at the top until the next flooding takes off additional hunks from the sides. Most gullies tend to branch out as they grow, but the tendency is more serious in the broad-bottomed type. Frequently, a few crossings by livestock are enough to start a branch, or tributary, gully; and as soon as the firmer, upper soil material is cut through by erosion into the soft underlying material, growth becomes rapid, much more rapid and destructive than in other kinds of gullies. Some of these undercutting gullies have been known to extend upslope 100 feet during a single rain.

Undercutting gullies (the same as broad-bottomed, or U-shaped) are the most difficult to control because of the instability of the understrata. When obstructions, whether dams or plantings of vegetation, are placed in them, floodwaters tend to cut out the soft material around the ends or beneath the obstructions and so destroy the effectiveness of such controls. An effective dam in this type of gully might easily need to be wider at the bottom of the gulch than at the top. Many thousands of dollars have been spent along high-

ways in the control of single gullies of this undercutting type.

In studying gullies as well as any other water channel, it is important to observe how currents are deflected from one side

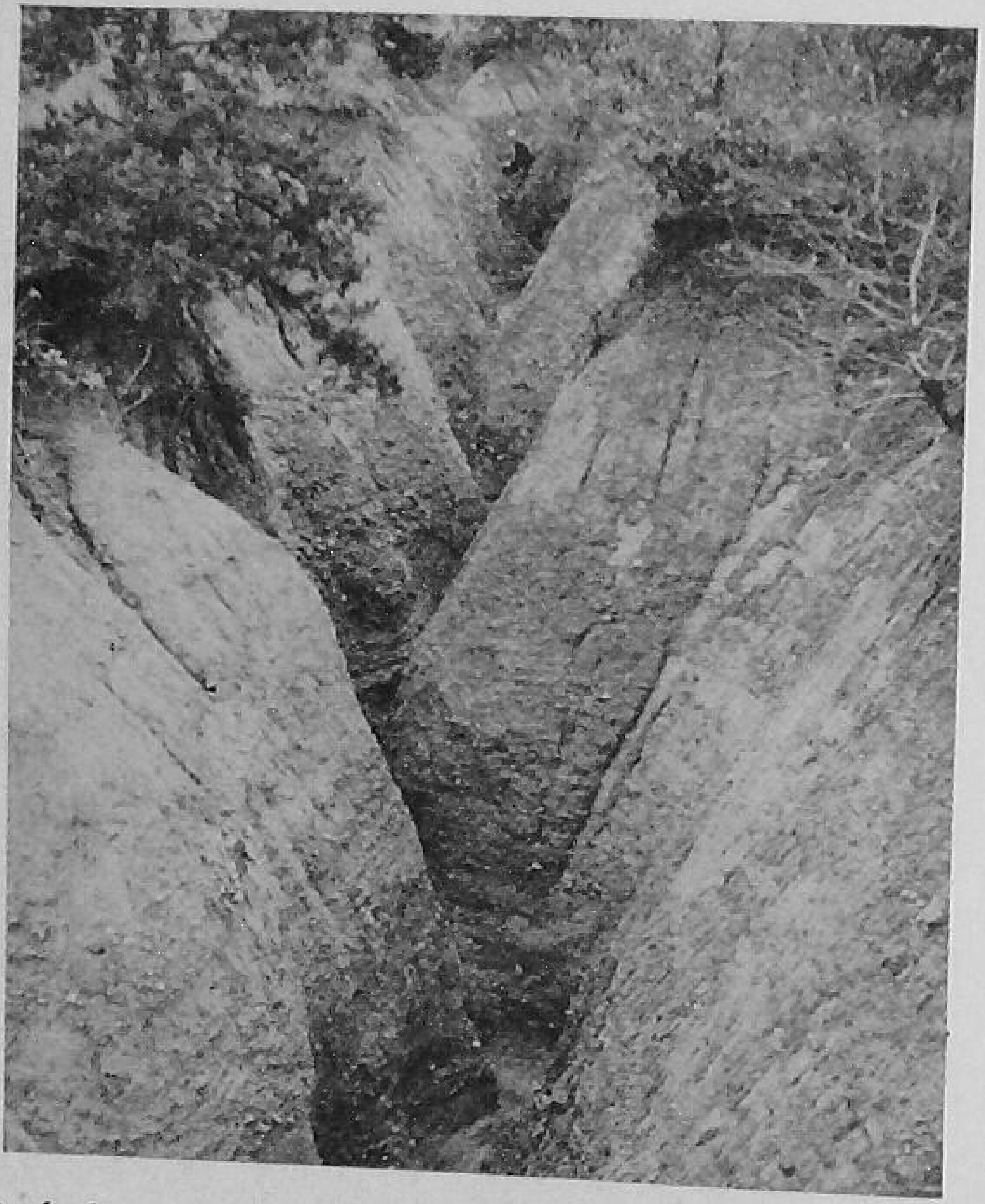

Fig. 33.—Pothole-gully scouring sometimes results in the development of a corkscrew curvature in gully bottoms. Gravelly limestone soil. Northwestern Georgia.

to another and how this action of water tends to cut away the banks at one place more than at another (more at the point where the deflected current comes in contact with the opposite bank). This behavior of flowing water is responsible for the crookedness of streams (the meandering characteristic) in gullies (wet-weather streams) as well as perennial streams. The tendency is illustrated by the corkscrew type of water flow in the V-shaped, corkscrew or pothole gully of Fig. 33.

Broad-bottomed gullies of the undercutting, or U-shaped, type, it should be noted, are less meandering than other gullies because the soft materials at the base of the sides tend to give way to the impact of currents rather than to resist and deflect the flow.

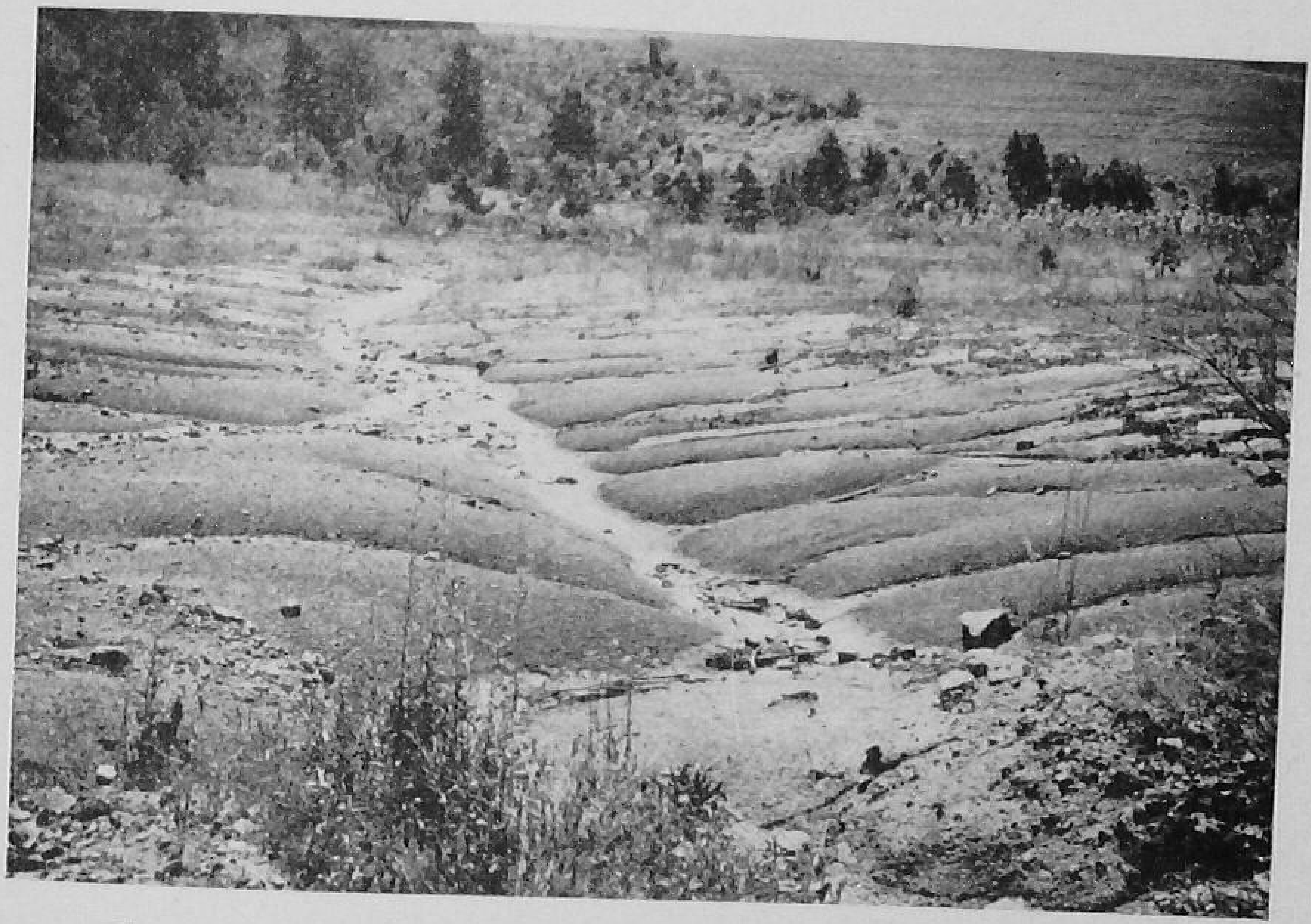

Fig. 34.—Broad, shallow gully on tough clay. South Carolina.

There are many other differences in gullies, but the most important for the beginner to recognize is the comparatively shallow kind that spreads out widely from the sides, as illustrated by Fig. 34. These gullies are sometimes as wide as they are long (lateral-extension gullies). They are most commonly associated with soils having tough layers somewhere below the surface that resist downward cutting and tend, when reached by eroding water, to direct subsequent washing toward the sides.

A form of gully cutting that is of great importance because it does so much damage is that caused by water cascading over the heads and sides of gullies, over dams, and over terraces whose channels have been filled with the debris of erosion. This type is frequently called *waterfall erosion* (Fig. 35).

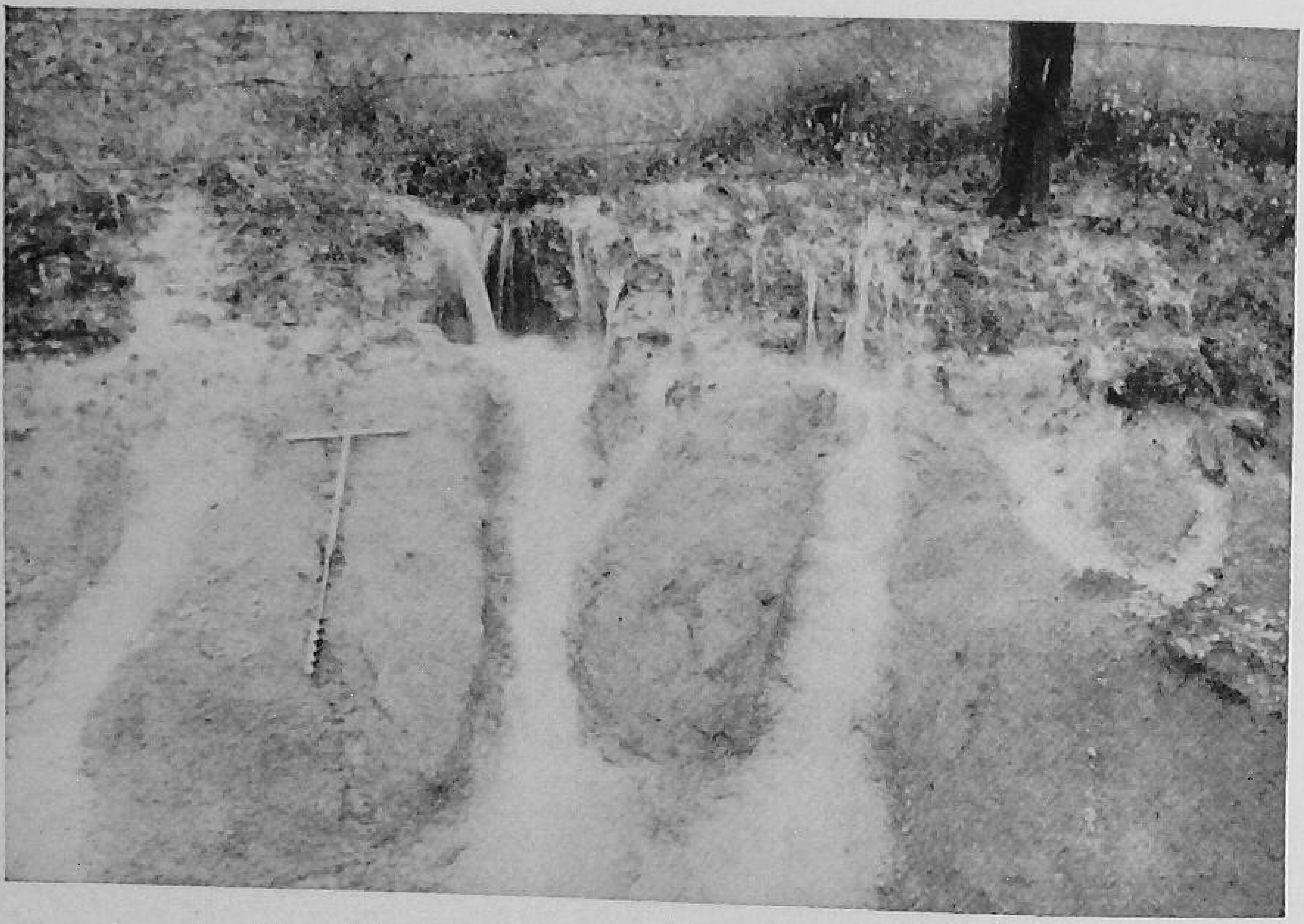

Fig. 35.—Waterfall erosion at head of gully.

In East-central, Southeastern, and South-central United States, gullies are known by that name; in the northeastern and north-central sections, they frequently are called *ditches*. In the Southwest (east of the Pacific slope), *arroyo* is the common name, although *wash* is frequently used for those having channel ways of shallow depth and exceptional width. In the Northwest gullies are sometimes called *coulees,* and in the Pacific Southwest, *barrancas*.

Assorting Effect of Water Erosion. Runoff from some soils, particularly sandy land, picks up and carries away the finer,

lighter particles by a selective, or washing-out, process known as *assortment* or *elutriation*, leaving behind the larger, heavier particles. Thus, sandy loam soil is sometimes changed to straight sand, and a loam soil of moderate sand content to a sandy loam. Under intense rains, this selective effect of runoff is not so pronounced, the tendency being more to cut away all the soil, bodily, by erosion.

The assorting effect of water is far more pronounced when the runoff, with its load of suspended soil, enters a stream. Because they float longer, stream flow carries the finer, lighter products of erosion much greater distances than the coarser, heavier particles. As a result, the less productive coarse material (sand, gravel, and sometimes cobbles) frequently is left as deposits (overwash) to damage valley lands. Also, much coarse material is left in stream channels on bars and riffles, and some is spread out in strips along stream banks and over flat alluvial plains where vegetation retards overflow water (Fig. 36). *Alluvial cones* formed where torrential mountain streams flow out onto flat land at the foot of slopes frequently contain much coarse material (Fig. 37).

Erosion by Wind. In its arena of activity, erosion by wind presents a problem of equal importance to that of water erosion. Often, it occurs in localities where water erosion also is active. Soil washing attains its most serious proportions on land with a considerable degree of slope and an intensive rainfall. Soil blowing, on the other hand, becomes an acute problem on both level and sloping areas affected by low rainfall.

Under conditions of normal ground cover and natural soil stability, wind erosion, like water erosion, proceeds very slowly. But in relatively flat and gently undulating, treeless regions, like the Great Plains, where the sweep of wind is almost unbroken by topographic obstructions, any violent disturbance of

Fig. 36.—Productive alluvial soil buried under nonproductive coarse sand by a flood resulting from a 9½-inch rainfall on Sept. 29, 1936. Eighteen Mile Creek, near Clemson College, S. C.

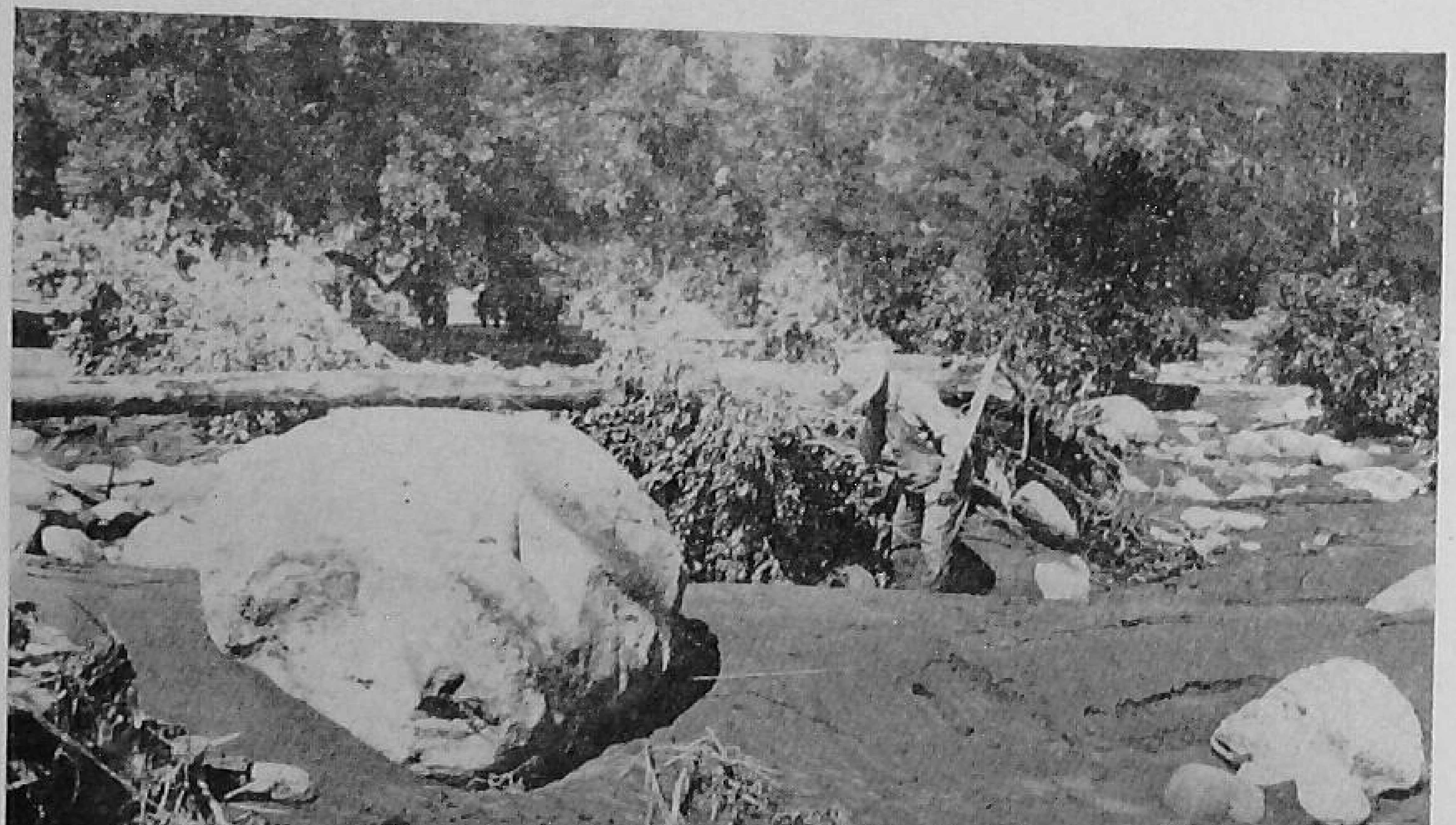

Fig. 37.—Citrus orchard damaged in 1938 by deposition of silt and rocks on alluvial cone of mountain canyon. Note size of boulders transported by the flood. Southern California.

the natural cover of vegetation is likely to bring on a tremendous increase in the effects of wind erosion.

When the grass is plowed up, the equilibrium of the soil is violently upset. Cultivated soil, depleted of the binding effect of grass roots and spongy organic matter that normally accumulates under a cover of grass, becomes much less cohesive. After periods of drought, it turns into a dry powdery substance, lying loosely over the surface of the land. This loose, dry material (the fine particles) is easily swept up by the wind and transported over long distances. The coarser, heavier particles left behind are blown along near the surface as *ground drift* to accumulate about obstructing clumps of vegetation, houses, farm implements, and fences.

Soils vary considerably in their resistance to wind erosion, depending generally on the size of the particles and the content of organic matter. Neither coarse sands nor heavy clays, however, are immune. Actually, the former are more susceptible and are liable to begin to blow immediately after plowing. The finer textured soils, especially those of mellow or granular structure, generally show the greatest resistance. They sometimes remain undisturbed through years of cultivation, although when subjected continuously to dissipation of their organic matter under cultivation, the granules or clusters of soil particles break down eventually to single grains, which, thus separated, are easily moved by the wind.

The action of wind, as well as water, on the soil is somewhat like that of a sieve. Wind picks up the lighter, more fertile soil particles and lifts them into the pathways of high air currents, which often carry them for hundreds and, at times, thousands of miles.

The coarser, less fertile grains of sand or soil skip and roll along the surface until they pile up in *drifts* behind any obstacle to their progress. A comparison of the soil material blown away by a dust storm with that left behind reveals in

striking fashion this assorting effect of the wind-erosion process.

Dust Storms. Early in 1937, a dust storm originating in the Texas-Oklahoma Panhandle country traveled northeasterly across many states and on into Canada. Soil material laid down by the storm on snow and ice in Iowa was collected and compared with samples taken from a small dune formed by the same wind disturbance near Dalhart, Tex. Analyses showed that the dust carried a distance of more than 500 miles contained ten times as much organic matter, nine times as much nitrogen, and nineteen times as much phosphoric acid as the dune material piled up in the general locality of the dust storm's source. The material that was transported to Iowa was found to be very much finer than either the dominant unplowed soil of the Panhandle section where the storm started or the dunes formed in that locality by the same storm. The wind-blown material contained no particles as coarse as the finest sand, but the unplowed grassland contained 79 per cent sand (of various grades), and the drifting dunes left behind 92 per cent sand.

Various measurements of the amount of dust in the air reported by observers indicated that more than 100 tons of dust per square mile fell in parts of the country affected by the great dust storm of May 12, 1934, which covered a vast territory extending from the vicinity of the Rocky Mountains to several hundred miles out over the Atlantic. It seems quite possible that this one storm deprived the Plains country of 200 to 300 million tons of soil—rather, that much of the most fertile constituents of the Plains soils.

In Europe, the amount of material that fell in Westphalia during the dust storm of 1859, supposed to have originated in the Sahara (a *sirocco*), is reported at 85.8 tons per square mile.

The popular conception of wind erosion is that it is confined to arid and semiarid regions. Although the most severe damage occurs in such regions, the process sometimes affects seri-

ously the more sandy soils of the high-rainfall regions. Along the Atlantic seaboard, for example, sand transported by wind from cultivated fields sometimes chokes drainage ditches and frequently damages young plants. Vegetable growers in parts of the Atlantic states, as in the vicinity of Charleston, S. C., sometimes practice strip cropping as a means of reducing abrasion by wind-driven sand. Muck and peat lands, also, are often strip cropped in the Great Lakes region to prevent the light soil particles from blowing away. Both shrubs and trees are planted in rows for the same purpose.

In some localities, for example in western Michigan, relatively unproductive sand, transported as ground drift, frequently covers up the adjoining flat farm lands and even falls into harbors to cause thousands of dollars in costs for dredging operations. The village of Singapore on the west coast of Michigan near Saugatuck, formerly an important point for shipping lumber, has been completely covered by drifting dune sand.

The small dust storms that play over dry, plowed fields under the force of gentle winds and the spiraling "dust clouds" (Fig. 38) of whirlwinds, so frequently seen over the Western landscape, generally do little individual damage. But they illustrate how soil can be lifted by the eddies and whirls and deflections of the wind.

The small blows increase in size with increased wind velocity; frequently, local dust clouds combine to develop big dust storms. With more land in cultivation and the period of cultivation lengthened, the Plains country today is experiencing in times of severe drought much larger dust storms than ever before. The big "black dusters" that from time to time during the thirties blew from the heart of the continent across to the Atlantic, were not previously known by the American white

Fig. 38.—Upper: local wind erosion by whirlwinds blowing, spirally, the loose, dry soil. Such diminutive duststorms are harmless. Lower: dust cloud "black duster" south of Lamar, Colo., on Highway No. 59, May 24, 1937. This kind of wind erosion does great damage.

man. Plainsmen had known the same type of dust storm for many years, but nothing so big and disastrous.

Questions

1. What are the principal differences between water erosion and wind erosion?
2. What is sheet erosion? What are rills?
3. Define gully erosion.
4. Name and define four types of gullies.
5. Which is the most troublesome kind of gully? Why?
6. What causes meandering in waterways?
7. What effect of erosion indicates the death stage of land?
8. What is an arroyo? Coulee? Wash?
9. What changes does flowing water produce on water-borne eroded material?
10. What is an alluvial cone?
11. How does topography affect wind erosion?
12. Explain the relation of cultivation to soil blowing.
13. What happened to the village of Singapore, Mich.?
14. What soils are most susceptible to blowing?
15. What effect does wind erosion have on the character of soil material? Water erosion?
16. How do these agencies affect the fertility of the soil?
17. What is a sirocco?
18. Define sand dunes.
19. What is ground drift?

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CHAPTER 5

Rates of Erosion and Runoff

PRESENTING:

- Diversity of Factors Affecting Erosion and Runoff
- Normal and Accelerated Rates of Erosion
- Comparison of Erosion and Runoff from Bare and Vegetated Areas under Contrasting Conditions
- Effect of Declivity on Erosion and Runoff under Clean Tillage
- Effect of Slope Length on Erosion and Runoff
- Effect of Rainfall Intensity on Erosion
- Effect of Season on Soil and Water Losses
- Effect of Crop Rotation on Erosion and Runoff
- Effect of Cropping Practices on Erosion and Runoff
- Effect of Organic Matter on Erosion and Runoff
- Comparison of Grass and Forest Effect on Erosion and Runoff
- Comparative Rates of Erosion and Runoff from Topsoil and Subsoil
- Effect of Biological Forms on Soil and Water Conservation
- Other Factors Influencing Rates of Erosion and Runoff

Diversity of Factors Affecting Erosion and Runoff. Vegetation, slope, soil, and climate all markedly affect erosion and runoff. Vegetative cover influences rates of rainfall runoff and soil removal more than any other single factor. Declivity of the land and length of slope also have important effects. Intensity of rainfall, condition of the ground with respect to moisture content, and openness of the soil (permeability) are

also contributing factors of great importance. When the ground is frozen, erosion obviously is less rapid than at other times. When wet soil freezes, the tendency is for more nearly complete closing of the openings through which rainfall enters the ground than when relatively dry soil freezes.

Intense rains cause much more erosion than gentle rains. Soil alone, as it varies from place to place, introduces a great variety of conditions that appreciably or profoundly influence rates of water absorption and, therefore, of runoff and soil erosion. Obviously, rainwater passes down into and through porous sand or gravelly soil much more rapidly than through dense clay. Again, the capacity of readily penetrable soils like sand, sandy loam, and loam to take up rainfall varies with the depth to sublayers of impervious material, such as dense clay, claypan, hardpan, and solid rock. And soils favorably charged with decaying vegetable matter are much more resistant to erosion than less spongy soils deficient in organic matter.

This wide range of variants cannot be ignored in planning for the control of erosion. Moreover, types of farming, grazing practices, and methods of cultivation introduce numerous other modifying conditions that must be given careful consideration.

Accordingly, these and other influences, separately and collectively in many instances, make the control of erosion and surface waters a difficult and complicated problem. On much land, however, effective soil conservation can be established through the use of simple practices. Unfortunately, these lands and conditions are not always readily recognized, so that the assistance of conservation specialists is required to insure the success of conservation work.

Normal and Accelerated Rates of Erosion. The normal rate of erosion from virgin Cecil sandy clay loam (a well-drained soil with red clay subsoil, derived from granite) on a 10 per cent slope, in the central part of the southern Piedmont, is

probably somewhere near 0.002 ton of soil lost per acre per annum. This is the average annual rate at which soil was lost from such land over a 5-year period under a good cover of forest, protected from fire—as determined by catching and weighing the soil removal from measured areas at the Statesville, N. C., Soil Erosion Experiment Station. Measurements over a longer period may change this figure slightly, but it probably is not very far from correct, since the measurements on which it is based have covered a considerable range of rainfall conditions and relate to the same soil and slope, under the same undisturbed forest cover.

Such a rate of soil removal means, according to computation, that if there should be no rebuilding of soil from beneath, about 575,000 years would be required to wash off the 7 inches of topsoil normally found on this type of land under its native cover of hardwoods. At such slow rate of surface removal, soil probably rebuilds from beneath fast enough to balance that washed off the top. At any rate, a layer of topsoil approximately 7 inches deep has been maintained for an undeterminable period in the southern Piedmont, under soil, slope, and forest conditions essentially identical with those where the foregoing measurements were made.

The time required to lose a 7-inch layer of surface soil from the same kind of land used continuously for a clean-tilled crop (cotton) would be 46 years, according to measurements made in an adjacent field, or about 1/12,500 times as long as under the protection of hardwoods. Where the land is completely bare of vegetation from year to year, only about 18 years are required to take off the full 7-inch depth of topsoil. In other words, under a good forest cover, the topsoil of this particular type of land would last, without replacement by building from beneath, about 32,000 times as long as under the condition of a

bared surface and, under grass, about 4,500 times as long as with a bared surface.[1]

The losses cited for this southern Piedmont land were used merely as an illustration. Measurements on other types of land in other parts of the country indicate the same general trend. In many localities, grass appears to be of about equal effectiveness as forest in holding soil.

The rates of erosion referred to here and, for the most part, elsewhere in this volume pertain largely to the effects of sheet washing, both normal and accelerated (for reasons of comparison). Rill erosion has taken place on the areas from which the measurements have been made, but no gully erosion has appeared. As yet, little quantitative information is available with respect to rates of gully erosion. Observation, however, indicates that where gullying is in progress, soil is removed at a faster rate than where the erosion involves sheet washing only or sheet and rill washing combined. Usually, sheet erosion accompanies the gullying process.

Comparison of Erosion and Runoff from Bare and Vegetated Areas under Contrasting Conditions. Measurements of soil and water losses made at soil and water conservation experiment stations together with other measurements and information from surveys, field observations, and the experience of farmers reveal the apparent universal effectiveness of close-growing vegetation toward increased soil intake of rainfall and conse-

[1] Since a 7-in. layer of topsoil appears to have been maintained in this region for indeterminate centuries, it seems reasonable to assume that under natural conditions soil is rebuilt from beneath at least as fast as it goes off from the surface. If the rate of surface removal as indicated by the measured 5-year average loss of 0.002 ton per acre per annum is anywhere nearly correct, it is apparent that topsoil builds up from subsoil clay at an extremely slow rate in this region on this particular soil.

Actual measurements of soil building on old eroded areas in the central Piedmont region, as determined by the age of second-growth pine, indicate that soil rebuilding at the immediate surface requires, under some conditions, at least 50 years to re-establish a layer much less than ¼ in. thick.

quent reduction of runoff and lessening of soil erosion. The general trend can be illustrated by citing certain summaries from more than a hundred thousand separate measurements, over periods ranging from 3 to 11 years. These indicate the effects of individual rains (and thawing of snow) under a great variety of conditions with respect to soil, slope, cover, cultural methods, and climate.

Briefly, the results of the numerous measurements on 13 important types of farm land, typical of many millions of acres of eroding lands, show average losses under clean-tillage operations of nearly 34 tons of soil per acre annually, together with a loss of more than 18 per cent of the rainfall as immediate runoff, as compared with an average soil loss of only 0.35 ton per acre per year and a water loss of only 2.7 per cent of the total rainfall where the land was used continuously for grass. (These amounts are averages and are used as representing approximate losses only.)

Without exception, average annual soil losses from the areas devoted to clean-tilled crops have been many times greater than from comparable areas heavily covered with protective vegetation, the excess ranging from about 6 to 2,955 times as much. The water losses as immediate runoff from the cultivated or exposed areas have shown a range of 2½ to 355 times the losses from the corresponding areas protected with permanent cover.

The average results of the thousand measurements of the effects from individual rains on these 13 important types of farm land show that under the exposure of clean tillage and fallow, soil is lost at a rate nearly 100 times as rapidly as from corresponding areas safeguarded with a dense cover of vegetation and that nearly 7 times as much of the rainfall is lost as runoff from cultivated land as from land protected with vegetation.

Measurements of Erosion and Runoff, Southwestern Wisconsin. The measurements made at the soil and water conservation experiment station near La Crosse, Wis., pertain to land that is considered representative of about the average condition of the more erodible of the important farming soils in southwestern Wisconsin and adjacent parts of Minnesota, Iowa, and Illinois as well as some of the steeper cultivated lands along the lower Missouri and along the Mississippi above the Missouri.

In the following table are listed the indicated lengths of time that would be required to wash off 7 inches of topsoil from Clinton silt loam of 16 per cent slope under four markedly different types of treatment: (1) grass, (2) corn, (3) a rotation of corn, barley, and clover, and (4) no cover of vegetation:

INDICATED TIME NECESSARY TO ERODE 7 INCHES OF TOPSOIL FROM CLINTON SILT LOAM, 16 PER CENT SLOPE

	Years
Grass	33,600
Rotation	40
Corn	11
Bare (fallow)	7

Measurements of Erosion and Runoff, Arkansas-Louisiana-East Texas Sandy Lands Region. The land on which measurements have been made is representative or approximately representative of one of the most important types of erodible land in the 48 million acres comprised in the predominantly sandy land area stretching from west of the Brazos River in Texas to the vicinity of Little Rock in Arkansas and southward beyond the Red River in Louisiana. From the standpoint of costly erosion, this large region represents an important problem area within the Cotton Belt.

In the following table are listed the lengths of time indicated as necessary to strip off 7 inches of soil material from Kirvin

fine sandy loam, in east Texas, under grass, forest, a 3-year crop rotation, cotton grown on topsoil, and cotton grown on erosion-exposed subsoil.

INDICATED TIME NECESSARY TO ERODE 7 INCHES OF SOIL MATERIAL FROM KIRVIN FINE SANDY LOAM

	Years
Grass (16.5 per cent slope)	171,500
Forest (12.5 per cent slope)	27,400
Rotation (8.75 per cent slope)	67
Cotton (8.75 per cent slope)	46
Cotton on subsoil (8.75 per cent slope)	21

Measurements of Erosion and Runoff, Southern Piedmont. The Cecil sandy clay loam is one of the most important and representative types of erodible farm land of the approximately 41 million acres in the important farm area of the southern Piedmont region (foothill section of the southern Appalachian region). It is interesting to note the tremendous differences in the time indicated as necessary to remove a 7-inch layer of soil (which represents about the average depth of the humus layer, or topsoil, of this type of land at the time of clearing) by erosion under different conditions of cover and treatment, as measured in North Carolina.

INDICATED TIME NECESSARY TO REMOVE 7 INCHES OF TOPSOIL FROM CECIL SANDY CLAY LOAM, 10 PER CENT SLOPE

	Years
Virgin timber	575,000
Grass	82,150
Rotation	110
Cotton	46
Bare ground	18

Quantitative data show that under a rotation of cotton-corn-wheat-lespedeza, erosion is only about one-third as severe as on the same kind of land, affected by the same rainfall, where cotton is grown continuously. The same type of land without

a cover of vegetation erodes more than 2½ times as rapidly as land in cotton and more than 4,000 times as fast as that in grass. Also, from bare ground, nearly 3 times as much water runs to waste as from the same kind of land in cotton and 100 times as much as from the same kind of land in grass.

Effect of Declivity on Erosion and Runoff under Clean Tillage. The importance of slope in relation to soil and water losses from cultivated land is revealed in the measurements of rates of erosion and runoff, under comparable conditions of soil, cover, and rainfall, presented in Table 3.

TABLE 3. EFFECT OF SLOPE ON ANNUAL SOIL AND WATER LOSSES UNDER CLEAN TILLAGE [1]

Soil and location	Period	Rainfall, in.	Length of slope, ft.	Slope, per cent	Crop	Soil loss, tons per acre	Water loss, per cent precipitation
Miles clay loam, Texas	1926–1937	20.73	97.0	0.0	Cotton	2.2	6.4
				1.0		5.2	15.1
				2.0		7.0	15.5
Muskingum silt loam, Ohio	1934–1936	36.46	72.6	8.0	Corn	60.0	30.4
				12.0		73.2	42.0
Houston black clay, Texas	1933–1936	34.90 [2]	72.6	2.0	Corn	10.6	13.4
	1933–1936	35.47 [2]		4.0		30.4	16.6
Kirvin fine sandyloam, Texas	1931–1936	40.82	72.6	8.7	Cotton	27.9	20.9
	1933–1936	43.00		16.5		72.0	14.6
Shelby loams, Missouri	1918–1931 [3]	40.37	90.75	3.7	Corn	19.7	29.4
	1931–1935 [4]	34.79	72.6	8.0		68.8	28.3

[1] Measurements at soil and water conservation experiment stations, Soil Conservation Service.

[2] Rainfall difference due to location.

[3] Columbia, Mo.

[4] Bethany, Mo.

In the instance of Houston black clay, at Temple, Tex., the average annual soil loss under corn for a 4-year period was at a rate nearly three times that from the same kind of land having a slope only half as steep, that is, 30.4 tons an acre from an area of 4 per cent slope as against 10.6 tons from a similar area having a slope of 2 per cent. From Kirvin fine sandy loam, near Tyler, Tex., the average annual soil loss was at a rate more than twice as rapid as that from a slope only about half as steep but otherwise comparable. From Shelby loam, at Bethany, Mo., it was more than three times that from the same type of soil at Columbia, Mo., where the slope is not quite half so steep.

There is no indication, however, that the rates of increase in soil loss conform with increase of declivity in accordance with any definite degree of regularity. For example, the corresponding soil losses from adjacent areas of Miles clay loam at Spur, Tex., have been at the rates of 5 tons an acre annually from cotton grown on a 1 per cent slope and 7 tons annually from cotton grown on a 2 per cent slope.

Under cultivation, water losses are usually greater from the steeper slopes, as the results presented in Table 3 show, but they frequently do not increase with increase of slope, under conditions otherwise comparable, nearly so rapidly as do the losses of soil. As a matter of fact, runoff sometimes is no greater and occasionally even less from steeper slopes, otherwise comparable, where the rate of soil loss, however, is greater. This point is illustrated in the results obtained on Shelby loam in Missouri, where the runoff from an 8 per cent slope was less (28 per cent of the total precipitation) than from a 3.7 per cent slope (29 per cent of the total precipitation), regardless of the fact that the soil loss from the steeper area was more than three times as great. Such differences probably are involved with complex interrelations of rainfall intensity, rates of water intake, soil character and condition, amount of material carried in sus-

pension by the surface water, and energy involved in these various mechanical operations.

Effect of Slope Length on Erosion and Runoff. Measurements of rates of erosion from various types of land in regions of different rainfall characteristics indicate that erosion frequently increases with increase in length of slope.* As well as can be determined with the information available, the intensification is due to the usual greater volume of water accumulating on long slopes and the consequent increased velocity of runoff.

Measurements indicate that on certain kinds of land, erosion does not invariably increase with length of slope; for example, from a slope 36.3 feet long, on Houston black clay, near Temple, Tex., the average annual soil loss, over a 6-year period, was 27 tons per acre with an intertilled crop, whereas the corresponding loss from a slope of the same declivity but twice as long was 24 tons, and from another four times as long (145.2 feet) the corresponding loss was only 22 tons an acre. In like manner, the water lost as runoff decreased with increase in length of the slope.

Runoff seems to be much more variable than erosion in its relation to length of slope. Average rates of water loss have been found to be less from the longer slopes of various land types, especially those which are highly permeable to water when dry. This appears to be due to the increased opportunity for absorption on these peculiar soils afforded by the longer time that it takes water to flow across the longer slopes, especially in the instance of rains of low intensity. Such slope-length effect tends to diminish or even disappear on soils of low permeability, especially during heavy rains. Absorption is generally high and runoff low on soils that crack deeply on drying—at least until the cracks close as the result of wetting and expansion (swelling) of the soil.

Effect of Rainfall Intensity on Erosion. Quick downpours of rain invariably cause more erosion than slow "drizzling" rains. The simple explanation is that slowly falling water has more time to soak into the soil than dashing rains that quickly overcome the intake capacity of the land and consequently run off rapidly, tearing up the soil and sweeping it in the direction of the nearest waterway. When the velocity of water is increased, its capacity to transport soil is greatly increased. Doubling the velocity of flowing water may increase its carrying capacity much more than two, four, or eight times, depending on the obstacles in the path of flow.

Effect of Season on Soil and Water Losses. Water erosion generally is most severe during summer and spring, especially in the humid East. In the Pacific Northwest, specifically in the Palouse Wheat Belt of southeastern Washington and adjacent Idaho and Oregon, much serious erosion is caused by snow melting under the impact of warm winds from the west (chinooks), usually from January to March, in fields that were summer fallowed the preceding season. August and September commonly are the months of most excessive soil erosion over much of the semiarid and arid grazing areas of the Southwest, because that is the season of intense showers. As a rule, erosion is most serious over the greater part of the Pacific Coast region in winter and spring, this being the season of heavy precipitation.

In general, the period of heaviest erosion by water is that season represented by a combination of unstable ground condition and intensive rainfall. This obviously is dependent on both climate and land use. In most humid sections, heaviest soil washing takes place in the spring or early summer on freshly plowed land or land supporting a sparse or thin cover of vegetation or crop stubble, provided the heaviest rains chance to fall at that time. In the same locality, the season of most

disastrous washing for the following year may be delayed until summer or late summer if the heaviest and most intense rains are by chance delayed that long.

Wind erosion is influenced by seasonal conditions in much the same manner as water erosion. It is most severe when the ground is loose and parched and bare of anchoring vegetation. In the Great Plains, it is generally most disastrous in late winter and early spring, owing to the frequency of wind of soil-transporting force at that time and also the scarcity of protective cover. However, wind erosion may be serious in time of protracted drought at any time of the year, not only in the Plains but in many dry-land areas west of the Plains, especially on sandy land bared of vegetation by cultivation, overgrazing, or crop failure.

Long periods of partial or complete protection from erosion are afforded by continuous cold weather that keeps the ground frozen or covered with a blanket of snow.

Effect of Crop Rotation on Erosion and Runoff. Since a good crop rotation provides, on the average, more cover of a protective nature than the continuous production of clean-tilled crops and improves the physical condition of the soil in addition by building up the supply of spongy organic matter, it is not surprising to find that rotations generally reduce erosion and runoff.

Summarizing soil losses from cotton grown under comparable conditions, results obtained in Oklahoma and North Carolina have shown an average acreage annual loss of 14 tons from rotation areas as against 23 tons from continuous production. Similarly, corn grown in Texas, Missouri, Iowa, Wisconsin, and Ohio has shown an average acreage soil loss of 28 tons from rotation areas as against 51 tons from continuous production.

Effect of Cropping Practices on Erosion and Runoff. Cultivation of intertilled, or row, crops on the contour instead of in the direction of slope (up and down the slope) is usually very effective in reducing both soil and water losses. This is particularly true where the contouring is properly done, which calls for actual surveying out of enough contour lines (level lines across the slope) to guide the plowing of an entire field.

An example will illustrate the effectiveness of contouring: Measured losses from a correctly contoured field on typical cotton land of the Texas Black Belt (Houston black clay, 3½ per cent slope) have averaged only 16.6 tons soil loss per acre a year and 9.2 per cent rainfall loss as against corresponding losses under otherwise comparable conditions of 27.8 tons of soil per acre and 18 per cent of the rainfall where the rows ran downhill.

Also, the use of strips of close-growing vegetation, such as grass, alfalfa, clover, and lespedeza, grown on the contour between parallel strips of clean-tilled crops is highly effective in controlling erosion and runoff. To illustrate: on the same Texas Black Belt soil as that referred to in the paragraph immediately preceding, it was found that under comparable conditions of land, on the same farm the same year, strip cropping (strips of vetch between strips of cotton) cut the soil loss from 16.6 tons per acre (where the entire field was in cotton and contoured) to only 0.7 ton and reduced the corresponding water loss from 9.2 per cent of the rainfall to 2.6 per cent.

Effect of Organic Matter on Erosion and Runoff. Incorporation of vegetable matter with the soil, whether in the form of compost or barnyard or green manures, is usually helpful in reducing erosion and runoff. For example, soil losses from typical southwestern Iowa cornland (Marshall silt loam of 9 per cent slope, at the Clarinda, Iowa, Erosion Station), used for corn (1) without manure, (2) manured with 8 tons an acre,

and (3) manured with 16 tons an acre, have been at the annual rates of 22, 9, and 4 tons per acre, respectively. Even bare soil has shown marked reductions in soil losses as the result of manure applied annually, proving the direct beneficial effect of adding organic matter (see Table 4). Similar results have followed the manuring of other important types of farm land in other parts of the country.

TABLE 4. ANNUAL SOIL AND WATER LOSSES FROM AN IMPORTANT TYPE OF FARM LAND TREATED WITH ORGANIC MATTER

Soil, slope, and location	Period	Rain-fall, in.	Manure, applied annually, tons per acre	Treat-ment	Soil loss, tons per acre	Water loss, per cent precipi-tation
Marshall silt loam, 9 per cent slope, Clarinda, Iowa	1933–1935	26.87	16	Corn	4.73	4.0
			8		9.24	7.4
			0		22.07	10.4
			16	Fallow	36.60	13.7
			8		46.07	17.8
			0		58.47	20.2

By improving the structural condition, organic matter improves aeration of the soil and increases its capacity to conserve moisture and deliver it readily to plant roots. It improves those soil conditions favoring root penetration and the growth of beneficial microorganisms. It aids in processing the inorganic constituents of the soil, changing unavailable materials into forms available as plant nutrients. It aids in conserving the easily soluble constituents of the soil as well as those contained in fertilizers applied to the soil.

All of these benefits are reflected in increased yield of vegetation, which, in turn, prevents soil and water losses through (1) the binding effect of the more vigorous and widely spread-

ing root systems produced and (2) increased protection of the ground surface from direct impact of rains provided by increased vegetative canopy. And the relatively abundant amount of organic matter supplied by the decaying roots of grasses or

TABLE 5. ANNUAL SOIL AND WATER LOSSES FROM FORESTED AND GRASSED AREAS FOR FOUR IMPORTANT TYPES OF FARM LAND [1]

Soil and location	Slope, per cent	Drainage area, acres	Rainfall, in.	Period	Cover	Soil loss, tons per acre	Water loss, per cent precipitation
Kirvin fine sandy loam, Tyler, Tex.	7.5	7.94	45.08	1933–1935	Woods	0.050	3.6
	9.0	0.89	42.12		Grass	0.054	5.5
	12.5	0.01	41.89	1933–1936	Woods	0.079	0.5
	12.5	0.01	41.89		Woods, burned	0.291	2.7
	8.7	0.01	40.53		Grass	0.036	0.6
	16.5	0.01	43.00		Grass	0.008	0.2
Vernon fine sandy loam, Guthrie, Okla.	4.8	5.62	31.62	1933–1936	Woods	1.57	3.6
	5.6	2.50	31.62		Grass	0.04	1.7
	5.17	0.01	33.42	1931–1935	Woods	0.017	0.2
	5.17	0.01	33.42		Woods, burned	0.195	6.1
	7.7	0.01	33.01		Grass	0.029	0.9
Cecil sandy clay loam, Statesville, N. C.	10.0	0.01	45.26	1932–1935	Woods	0.002	0.1
					Woods, burned	0.627	3.6
					Grass	0.012	0.3
Muskingum silt loam, Zanesville, Ohio	12.0	2.23	36.46	1934–1936	Woods	0.01	1.2
		3.57			Grass	0.13	9.8
		0.01			Woods	Trace	0.1
		0.01			Woods, burned	Trace	0.3
		0.01			Grass	0.031	7.0

[1] Measurements at soil and water conservation experiment stations, Soil Conservation Service.

legumes is of great value in binding soil particles together in a way that increases resistance to wind or water erosion when the land is subsequently plowed.

Comparison of Grass and Forest Effect on Erosion and Runoff. Erosion proceeds with such extreme slowness under a good cover of grass or woodland growth old enough to have accumulated a layer of *forest litter* or *leaf mold* over the forest floor

that the effect is restated here as a matter of emphasis. Table 5 shows the almost insignificant rates of soil loss and the usual very low rates of runoff from four extensive and important types of farm land. In only a single instance has the soil loss exceeded 1 ton per acre in 1 year. In some instances, only traces of soil have been lost; and in no instance has the water loss been as much as 10 per cent of the total precipitation, averaging for the 19 average measurements recorded a loss of only 2.53 per cent of the total precipitation.

On Cecil sandy clay loam of 10 per cent slope near Statesville, N. C., the loss of soil from virgin woodland has averaged only 1/500 ton per acre annually over a period of 5 years; whereas the corresponding loss from grass has been at the rate of only 6/500 ton per acre annually. The corresponding losses of water have been only one-tenth and three-tenths of 1 per cent of the total precipitation, respectively. As previously noted, these losses are so small that soil probably builds from beneath as rapidly as it is removed from the surface.

Comparative Rates of Erosion and Runoff from Topsoil and Subsoil. Usually, erosion speeds up as the more absorptive, humus-charged topsoil is washed off to expose sublayers usually of lower absorptive capacity and frequently of less stable nature. Measured rates of soil and water losses from eight important types of land, representing (at least fairly closely) many millions of acres of farm land, show that the losses have been greater where the subsoil was exposed under similar conditions of slope, treatment, and rainfall. The average results show an annual loss from topsoil of 31.6 tons of soil per acre, accompanied by an average runoff of approximately 16 per cent of the total rainfall, as against corresponding losses from subsoil of 45 tons of soil and 22 per cent of the precipitation.

Effect of Biological Forms on Soil and Water Conservation. To a degree much more profound than is generally realized,

erosion is influenced by the millions of organisms that inhabit the soil. This influence may be direct, as in the case of such organisms as earthworms, various insects, and rodents, or indirect, as in the case of those forms grouped under the general heading of microscopic organisms.

As long ago as 1881, Darwin called attention to the fact that earthworms aid in the denudation of English soils. As a result of careful observation and weighings, he calculated that a large quantity of earth passes through their bodies and is deposited on the surface of every acre (about 10 tons annually). Castings left in this way on pasture land are frequently washed downslope with heavy rains, so that soil is lost even where the ground is protected by a dense sod. Although quantitative data pertaining to this point are not available for the United States, there is evidence that similar activities take place in the humid parts of the country. On the other hand, earthworm burrows often extend to a depth of 3 or 4 feet or more and serve as water channels to increase the intake of rainfall and to facilitate favorable internal circulation of moisture. Earthworms also aid materially in carrying organic matter below the surface. In working over the soil, they improve its physical condition, especially with respect to the development of a favorable crumb structure, thus aiding to make soil more permeable to water.

In the arid and semiarid Western regions particularly, rodents play a part in erosion damage by bringing loose earth to the surface, where it is subject to wind and water erosion. Especially in overgrazed areas, the influence of such forms as the gopher, the prairie dog, and the kangaroo rat may sometimes be considerable. The chief effect of these mammals and of various insect forms, however, lies in their destruction of vegetative cover. The grasshopper has been responsible for exposing many areas to the beat and wash of rain and the lash of wind by stripping off the coverage of vegetation.

The biological effects on the soil of microorganisms, such as protozoa, bacteria, fungi, and algae, are enormously important, even essential to productivity. As Selman A. Waksman, microbiologist of the New Jersey Agricultural Experiment Station, points out (*Soil Conservation,* January, 1938): "For every plant

Fig. 39.—Photomicrograph of fungus mycelium holding soil particles in clusters to form granular structure.

or animal living on the surface of the earth, there are hundreds of kinds of lower forms of life which lead their entire existence in the soil and which give life to the soil itself." The influence of these organisms depends on their ability, especially marked in the case of bacteria and fungi, to break down fresh organic matter.

When organic material, such as barnyard manure, green manure, and crop residues, is incorporated with the soil, it is attacked by fungi and bacteria and is broken down into various

organic compounds. Among these products are ammonia, carbon dioxide, nitrates, and various organic acids which tend to enrich the soil solution by converting unavailable constituents of the soil into available nutritive forms.

From the standpoint of soil conservation, the activities of soil microorganisms may be considered both helpful and harmful. The breakdown of organic matter with the production of nitrates is essential to crop production. But the continued destruction of soil organic matter under cultural practices may create conditions favoring erosion, such as loss of soil sponginess and cohesiveness. On the other hand, the action of these diminutive organisms tends to develop desirable crumb or granular structure that offers marked resistance to erosion and favors easy penetration by plant roots and rainwater. Molds, for example, sometimes form entwining growths around soil fragments or crumbs, thus providing considerable stability to the soil (Fig. 39).

Apparently, then, it usually is necessary in farm practice to restore organic matter to the soil by the use of manures, green manures, and crop residues as well as by growing in rotation those plants which supply vegetable matter through the decomposition of their roots.

Other Factors Influencing Rates of Erosion and Runoff. Various factors other than those previously discussed materially influence rates of soil and water losses. As a matter of fact, every obstacle in the path of wind or running water retards the rate of movement and consequently the cutting and transporting capacity of these powerful agencies. Every plant, every patch of stubble, every stone and clod, every inequality of the ground surface (hummock, depression, basin, or change in declivity, each contour ridge or furrow) and every hedge, fence, and building deflects wind or retards runoff, with the result of

reducing their power to pick up and move soil out of fields and pastures.

Even weeds reduce erosion, although not so effectively as grass. As compared with corn, weeds have caused a reduction of runoff on some types of land by more than a third and of erosion by more than half, according to actual measurements. Russian thistle, at one time looked upon as an insufferable pest in the Great Plains and other low-rainfall regions of the West, has proved itself a helpful plant for checking soil drift by wind (as well as valuable for emergency feed in time of drought).

Removal of stones larger than 2 inches in diameter from an important type of stony soil resulted in the loss of twice as much soil as from a comparable area with the stones left in place and increased the tendency of the land to gully.

A covering of vegetable litter (*vegetative mulch* or *stubble mulch*) serves as a powerful deterrent to erosion and a strong stimulant to rainfall absorption. For example, the soil and water losses from comparable land in the central Piedmont region (Statesville, N. C., Erosion Experiment Station) were approximately 0.2 ton of soil per acre and 10 per cent of the precipitation where 2 inches of pine needles were scattered over the surface every fall (about 23 tons per acre) as compared with the very serious losses of 32 tons of soil and 16 per cent of the precipitation from continuously grown cotton.

Weaver and Noll (*Univ. Neb., Dept. Botany Bull.* 11) found wide differences in the rate of runoff and erosion from unplowed prairie land and overgrazed pasture in Nebraska. With respect to this, they say: "Runoff on a 10° slope from 26.88 inches of rainfall during 15 months was 2.5 per cent from prairie, 9.1 from overgrazed pasture, and 15.1 per cent from a pasture entirely bared of cover by close grazing. . . . No measurable amount of soil eroded from the prairie, only a small

amount from the pasture, but 5.08 tons per acre were lost from the bare area."

Questions

1. What are some of the more important physical factors affecting erosion?
2. Compare normal and accelerated erosion.
3. How fast is topsoil built up from raw subsoil material?
4. Give an example of rates of soil loss from clean-tilled land. From grass. From crop rotation.
5. What effect does steepness of slope have on erosion under clean tillage? Under dense cover? What is the effect of length of slope?
6. Why does soil erode faster under intense rains than with gentle rainfall?
7. How does season affect rates of soil erosion?
8. Compare effects of contour cultivation with downhill cultivation.
9. Why do erodible soils need organic matter?
10. Compare rates of soil removal by erosion from topsoil and subsoil.
11. Name three different ways in which animals and microscopic organisms may influence soil to retard runoff and erosion.
12. Do vegetative mulches impede rates of soil erosion? Explain.
13. What effect do weeds have on erosion? Stones scattered over the surface?

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CHAPTER 6

Climate and Soil Erosion

PRESENTING:

Climatic Elements Influencing Erosion
Relation to Soil Formation, Leaching
Relation of Precipitation to Soil Erosion
Relation of Wind to Soil Erosion
Relation of Temperature to Soil Erosion

Soil erosion is intimately related not only to vegetation, kind of soil, and land form but to such climatic elements as wind velocity, rainfall intensity, and temperature. Thus, from climatic zone to climatic zone, erosion varies in the rate at which it occurs and the form that it assumes.

Soil conservation problems must, therefore, be approached with a clear knowledge of the climatic environment.

Climatic Elements Influencing Erosion. Precipitation, evaporation, temperature, wind, and relative humidity are the most important climatic elements. When conditions in Southeastern United States are compared with those of the southern Great Plains, the significance of these climatic factors becomes immediately apparent. In the Southeast, summers are hot and long, winters mild and short, rainfall is moderate to heavy throughout the year, relative humidity is high, and wind velocities are abnormally high only during the hurricane season. Correspondingly, forest constitutes the natural vegetation; soils are deep and generally acid; streams are numerous; and hills are of rounded form. In contrast, summers are long and

hot on the southern Plains; winters are moderately cold; rainfall is low and mainly concentrated in the summer; evaporation is rapid, especially in summer; and wind velocities are high throughout the year. Short grass is the natural vegetative type. Soils are only moderately deep and are usually neutral to slightly alkaline; streams are few; and where hills occur at all, they tend to display sharp angles in their surface features.

In these contrasting climatic environments, soil erosion progresses at different rates and in different ways. In the Southeast, gullying and sheet washing cause the greatest damage; in the southern Plains, soil stripping and accumulation of ground drift by wind erosion are the principal hazards.

Climate determines the most favorable conditions for any particular kind of vegetation; it sets limits beyond which plants cannot penetrate. Such trees as the southern cypress are confined to warm, moist climates. Aspen, on the other hand, is restricted to cool regions.

Relation to Soil Formation, Leaching. Climate has a profound influence on the distribution of soils. This can best be understood by considering the way in which soil is formed. Through chemical and physical weathering, rocks are fractured, splintered, pried apart, and dissolved to form a mass of material consisting chiefly of rock fragments. Climatic conditions determine to a large extent how rapidly and in what ways this primary weathering process takes place. As soon as a few inches of fragmented material have accumulated, the climate begins to participate in actual soil development. If the rainfall is high and the evaporation low, water percolates down through the material, carrying fine particles in suspension and dissolved matter from the top downward into the lower portions of the soil. With high evaporation rate and low rainfall, the *leaching,* or solution, process does not take place to any such degree. Instead, water-soluble constituents tend more to re-

main distributed throughout the soil. For this reason, dry-climate soils are invariably higher in content of soluble constituents than similarly textured soils of humid regions. Sometimes the soils of arid regions accumulate such soluble salts in amounts sufficient to retard or prevent normal growth of most plants (alkali soils).

Temperature is also important; for if the temperatures are high, then chemical action proceeds rapidly and certain changes occur within the soil that could not take place at lower temperatures. As plants begin to grow, they also influence the soil; they remove certain constituents from it and on decaying add organic matter (humus) to it.

In topographic forms is found another example of the influence of climate on the landscape. Gentle, rounded slopes (Fig. 40) are characteristic of humid areas where plant cover protects the land against violent erosion by running water. Sharp angles, deeply entrenched canyons, cliff-bounded mesas, and "pedestal" rocks are typical of arid regions (Fig. 41) where the water runs off rapidly because of the lack of natural vegetation and where the wind, carrying sand particles as tools, abrades the bare rock surfaces and scours the basin floors. Between these two extremes exists a variety of intermediate conditions, all of which are, in some measure at least, related to climate.

Gullying and sheet wash represent the principal effects of soil erosion in humid lands—the effects of running water. Wind is effective chiefly in arid and semiarid climates. Ice action (glacial scour) is limited to the cold climates of high altitudes and polar regions.

Relation of Precipitation to Soil Erosion. The relation between precipitation and erosion is very direct. The amount of water carried by streams or gullies that cut headward or laterally to erode the land is dependent on the amount of precipita-

Fig. 40.—Rounded topography characteristic of humid-climate land forms. The forested mountain in the background is of rounded form; the valley is rounded in its general shape; and the hills in the valley are rounded hills. Limestone Valley country, Maryland.

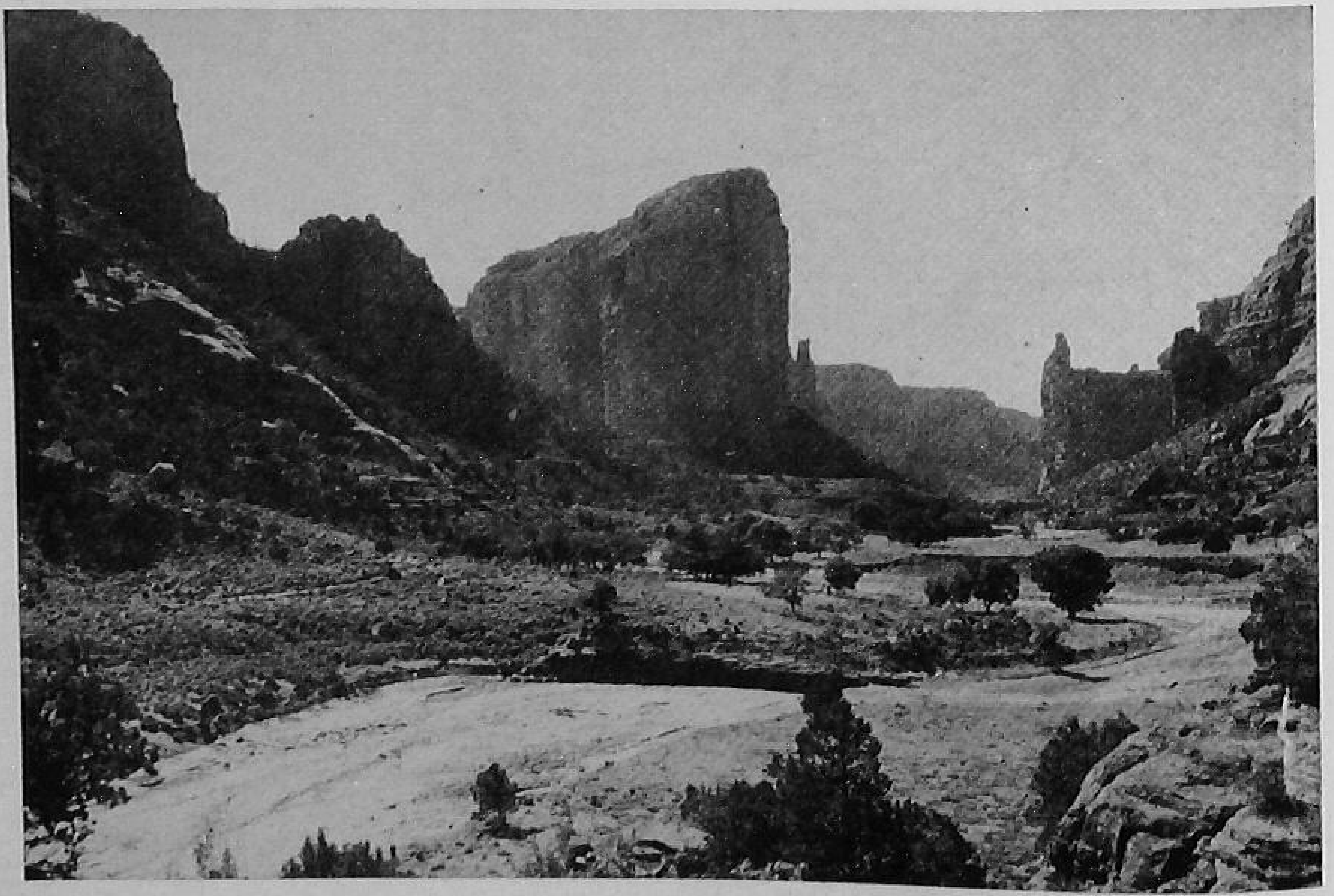

Fig. 41.—Angular, vertical-walled land-form characteristic of much dry-climate country. Arizona.

tion. Similarly, the amount of precipitation determines, within limits, the amount of water that can seep into the soil to aid plant growth. The kind of erosion that occurs and the amount of soil removed depend largely on the characteristics of the rainfall.

Rainfall intensity is closely related to the amount and type of erosion. The amount of soil removed by sheet wash and the rate of gully cutting are largely dependent on the rate of rainfall. Gentle precipitation causes little soil movement; intense rainfall results in more rapid soil removal through the operation of running water, as previously pointed out. Rainfall intensities are highest in summer and lowest in winter over most of the United States. Since, however, certain parts of the West Coast receive mostly winter precipitation, the generalization does not hold in such areas. It is necessary to know the nature of regional rainfall in order to adjust conservation and cropping practices to provide adequate protection for the land during those months which are most likely to experience high-intensity precipitation.

The most intense showers are usually local and of short duration. Although intensities are usually highest during summer and lowest during winter, rainfall durations are generally shortest in summer and longest in winter. Important differences obtain, however, from region to region, and these differences are particularly important in their bearing on the flood hazard. Floods on large watersheds generally are associated with rains of long duration; and in those areas where melting snows may contribute to the stream flow, it is essential to know the spring-rainfall characteristics not only with respect to expected intensities but also with reference to rainfall duration.

Since drought leads to crop failures and consequent exposure of soil to blowing and since it is impossible on some lands to effect erosion-prevention measures without including land-use

adjustments, the frequency of rainless periods of varying length and at different seasons is an important climatic index in soil conservation work. The drought problem is, of course, most acute in the low-rainfall parts of the country. Dust storms and crop failure have called attention particularly to the Great Plains region. The eastern portion of the Plains is less subject to drought than the part farther west, but this is not the only comparison to be made. There are seasonal contrasts also. Along the eastern border, the length of rainless intervals is less in spring than in summer, rainfall being moderately reliable during both seasons. Farther west, however, as in the Texas Panhandle, spring becomes a particularly hazardous season, whereas summer is the most reliable season for precipitation. Such shifts in drought hazard from season to season must be taken into consideration in adjusting land-use practices in order to decrease soil erosion.

Relation of Wind to Soil Erosion. That wind is an active agent of erosion is well known. However, it is customary to think of wind action as being limited largely to semiarid and arid regions. Although it is true that the most spectacular and widespread evidences of wind scouring and deposition are found in these regions, the humid areas also are subject to wind erosion, as previously noted. Throughout the world, land without a protective cover is subject to some degree of alteration by wind. Soil particles are mixed by shifting or swirling air currents; the coarser grains and fragments or clusters of soil grains are driven across open country by a process of rolling or short leaps (saltation). The finer material is transported in suspension over long distances. Coming to rest, the wind-driven, coarser soil particles and fragments that do not travel long distances develop into troublesome sand dunes, clay dunes, and vast expanses of sandy waste.

Like running water, the effectiveness of wind in causing erosion is dependent on the velocity and turbulence and on the

degree to which the soil is protected. If the land is bare, even winds of low velocity may remove a great deal of material. If the vegetation is profuse, wind velocities must be of hurricane magnitudes to produce soil loss.

In the Great Plains, wind erosion has been especially active and spectacular because velocities are high and much soil has been exposed through plowing. Drought, particularly in the spring, has added to the wind-erosion hazard. Under such circumstances, crops have failed to mature after planting, and the soil has remained exposed at that particular season when velocities are the highest and when turbulent movement in the atmosphere (swirling effect that aids wind to gouge out soil) is most common.

Although wind is potentially an agent of erosion in all climates, ordinarily it acts in humid areas only in soil mixing through the moving of soil particles short distances along the ground or through short flights of dust. If the land is bared, however, excessive wind erosion may develop, especially on sandy land and muck. In arid areas, the difficulties of combating wind erosion are very great, since it is often impossible and always hard to establish an effective vegetative cover. But in any climate, the wind, when provided with a bare dry soil on which to operate, can rapidly impoverish or ruin good land.

Relation of Temperature to Soil Erosion. Temperature acts in two ways to influence erosion. Through its effect on weathering processes, it participates in the preparation of material for ready transportation by water or wind. Both chemical and physical weathering involve the temperature factor. Solution and chemical reactions take place faster at higher temperatures. In the tropics, this is evidenced by the profound alterations that the soil undergoes and by the depth to which these changes are effective. Deeply weathered soil is a characteristic of hot, moist regions; in cold lands, on the other hand, the weathered soil

mantle is relatively thin because of retardation of solution and chemical action.

Physically, temperature is active in disrupting rock surfaces through alternate heating and cooling and through the wedge action of ice formed from water in the cracks and joints of rocks. Similarly, with the freezing of water in the surface soil, *frost heaving* occurs and serves to loosen the soil so that the particles and aggregates can be more easily carried away. Often the more sunny slopes (southerly slopes north of the equator, northerly slopes south of the equator) suffer more from erosion because of such factors as less freezing and sparser vegetation. Sudden rises of spring and sometimes winter temperature frequently cause rapid melting of snow to induce excessive runoff and erosion.

Questions

1. What are the most important climatic elements that affect erosion?
2. How does climate affect topography? Give an example.
3. How does slope exposure affect erosion?
4. Under what type of climate is soil leaching most active?
5. How does climate relate to soil formation?
6. At what season are rains most intensive in various regions?
7. At what season is drought most hazardous in the Texas Panhandle?
8. What is the principal effect of soil blowing in a humid climate?
9. Why are soils deeper in the humid tropics than in cold lands?
10. What effect does wind turbulence have on erosion?

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CHAPTER 7

Rainfall Penetration

PRESENTING:

- What Becomes of Rainfall
- Water Intake
- Effect of Tillage on Intake of Rainfall
- Effect of Organic Matter on Intake of Rainfall
- Effect of Muddy Water on Intake of Rainfall
- Methods for Increasing Intake of Rainfall
- Need for Increased Soil Storage of Rainfall

In preceding chapters, the physical aspects of rainfall penetration into the soil were broadly defined. At this point, it becomes necessary to describe the processes in more detail because of the extreme importance of the subject to soil and water conservation, flood control, replenishing underground water supplies, and increasing the productivity of the land. Previously, the terms *water intake* and *water absorption* have been used synonymously. Now, it becomes necessary to sharpen the definition and to show their relation to other forms of water that contact the land as well as to the erosion process.

What Becomes of Rainfall. When water comes in contact with sloping land in quantity exceeding immediate surface evaporation, part or all of it normally enters the soil. If the amount exceeds the immediate intake capacity of the soil, the excess flows along the surface as *runoff,* provided obstacles are not present to detain it. It is this runoff which produces water erosion.

Where liberal amounts of water enter the soil, part proceeds downward to the ground-water level (water table), frequently beyond the reach of ordinary plants; another part, retained within the upper portion of the soil, is partly utilized by plants and finally lost in the form of *transpiration* (the nutrient-charged moisture that aids plant growth by passing from the soil up through the plants and on into the air). Still another fraction is lost as direct evaporation from the ground surface. The proportion of the total precipitation that is finally disposed of in one or more of these forms (runoff, evaporation, transpiration, percolation, absorption) is greatly influenced by the quantity and intensity of rainfall and by the soil type, slope, kind and density of vegetative cover, surface roughness, and such artificial barriers to runoff as contour ridges, terraces, stripped crops, and water traps, as well as such factors as soil and air temperatures and wind velocity.

Obviously, if it were possible to cause all precipitational water to enter the soil somewhere near its point of contact with the land, there would be no runoff and, therefore, no water-erosion problem (and a much less serious wind-erosion problem, also). Although this is commonly impracticable on cultivated steep land in regions of heavy and intensive rainfall, one of the first objectives in any comprehensive soil and water conservation undertaking involving erosion is to manage the land so that the largest possible portion of the rainfall enters into the body of the soil (the soil profile, composed of soil, subsoil, and substratum, as illustrated by Fig. 42).

An indication of the large practical possibilities of soil intake of rainfall is seen in the vast storage space for water that is contained in the soil itself. If the water-holding capacity of all soils is assumed to be $33\frac{1}{3}$ per cent of the volume (soils not uncommonly have a 50 per cent or greater capacity), a 3-foot soil section would contain, if filled, 12 surface inches of water.

Even 1 surface foot of soil would have a theoretical storage capacity of around 4 inches. Achievement of water intake up to the practical water-holding capacity of a soil will depend primarily on surface and subsurface conditions of the land

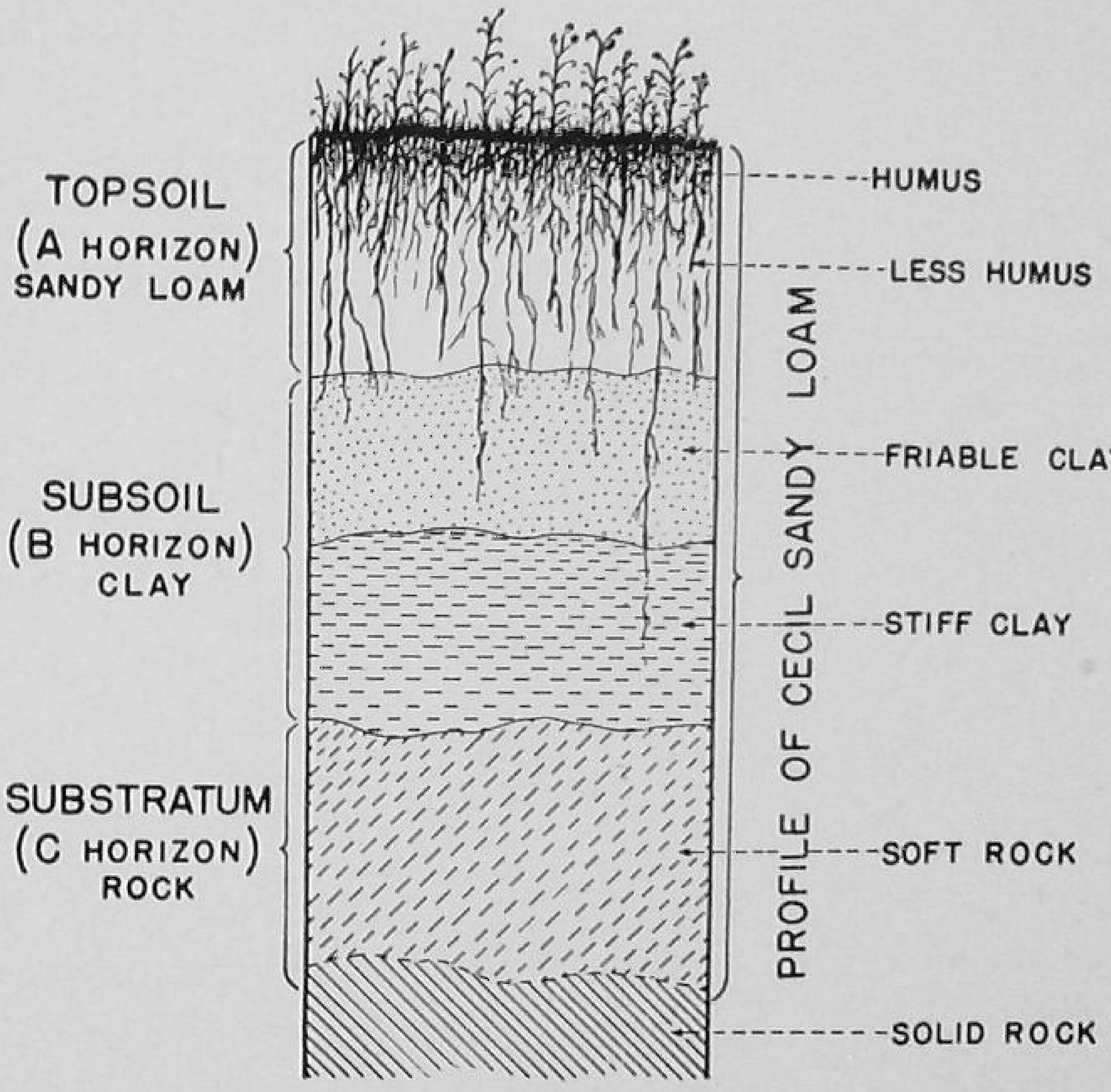

Fig. 42.—Profile of a virgin soil.

favorable to rapid infiltration; the capacity for retention of such infiltered water (absorbed water) will depend principally on subsurface conditions unfavorable to excessive loss by percolation.

Water Intake. The movement of water from the surface into the soil by way of openings (natural pores, cracks, root and animal holes, and cavities introduced by tillage) is known as *infiltration* or *water intake*. That part of such intake which moves down through the soil and sublayers beyond the normal

reach of plants—down to the water table or ground water or onward by way of porous beds or underground openings to surface outlets, as springs or seeps—is defined as *water of percolation* (or gravitational water). In the practical sense, percolation largely has to do with the water that moves through openings large enough to favor relatively free flowage under the pull of gravity. If the openings through the soil profile are large, percolating water may move beyond the reach of plants so rapidly that it is of little benefit to them.

That part of the water intake which is retained in the upper part of soils penetrated by plant roots is known as *water of absorption*. Much of this water is available to plants (available soil moisture) where the soil and subsoil are sufficiently tractable or soft for the roots to penetrate the material in search of moisture. Part of the soil water, apparently, is held as exceedingly thin films around soil particles with such force as to be unavailable to plants and incapable of moving from particle to particle by capillarity (unavailable soil moisture). For example, a "bone-dry" soil in which most plants will not live over any considerable period still contains uncombined yet unavailable water. The dividing line between available and unavailable soil water is usually referred to as the *wilting point*.

Recent studies have shown that the intake rate for different soils varies widely. These variations are closely related to (1) total amount of *pore space* (cavity) and (2) average size of the openings. Other things being equal, soils having a large combined pore space as well as large individual spaces between the soil particles or clusters of particles (granules) have water-intake rates much higher than soils whose individual openings are small. By the same token, soils of large total pore space have greater capacity for potential water storage, provided the individual orifices are not so large as to favor excessive percolation. On the other hand, very fine-textured, dense soils (clay

soils) with large potential storage capacity may not be able to avail themselves of such capacity because of slow intake due to the small diameter of the individual openings (retarded by surface-tension effect), especially where the slope and other surface conditions favor rapid runoff. With respect to *available moisture,* however, those dense clay soils having exceedingly small pores may contain only a small supply regardless of their high water-retaining capacity because they are so dense as to impede both circulation of moisture and penetration by plant roots in search of moisture. Such soils are difficult to drain; and in dry weather, they tend to crack into resistant blocks that become so hard about the surface as to trap or encase the contained moisture and so hold it unavailable to plants.

The results of recent rainfall-intake studies indicate that the term *saturated soil,* commonly employed for soil supposed to be so wet that it is incapable of taking up any more water, frequently has little meaning beyond a general qualitative expression. Some of the more open-natured soils like Ruston sandy loam of the southeastern Coastal Plain region have been found to continue taking up water after hours of artificial rainfall. This soil (to which 14.4 inches of water had been applied over a 3-hour period, 24 hours previously) was still taking in water at a rapid rate following a steady 3-hour application in amount sufficient to keep the surface covered. The rate of intake by this permeable soil was nearly as rapid toward the close of the test as in the beginning: 1.9 inches during the third hour as against 2.3 inches during the first hour.

These measurements of water intake, together with others made in other parts of the country, indicate that most soils continue to take in water after prolonged periods of rainfall. True, the point of saturation is approached in the instance of some soils (dense clays, particularly), but usually infiltration continues in some degree under almost all conditions. Precise

saturation points have not been determined for a sufficient number of soil types (if for any) to define the exact conditions under which soils, not subject to actual waterlogging because of occurrence in water-holding depressions, cease to take in water. It appears that hidden openings leading into the reservoir of the subsurface continue to conduct water into the soil under conditions that would seem sufficient to prevent any such intake. Frequently, perhaps usually, soils that are frozen or covered with what appears to be an impermeable sheet of ice still take in water. This probably means that openings still exist—holes and cracks in the ground as well as in the blanket of ice.

Effect of Tillage on Intake of Rainfall. Soil-management practices have much to do with rates of water intake. Plowing, cultivating, subsoiling, or other stirring normally increases, temporarily at any rate, the openness of a soil if the soil is of a kind or is in condition to fracture—break up—by such an operation. Waterlogged soil and excessively plastic clay (putty-like or "soapy") do not fracture readily and consequently are not likely to be benefited very much by any kind of stirring. Musgrave and Free have shown (*Jour. Am. Soc. Agr.*, vol. 28, 1936) that for the types of land studied, the rate of rainfall intake on land plowed 4 inches deep averaged 0.99 inch an hour and where plowed 6 inches deep, 1.20 inches, as against an intake of only 0.77 inch where there was no cultivation. The effects of cultivation on *soil porosity* (openness) and infiltration, however, are generally transitory, lasting only until the soil settles back, under the effect of subsequent rains, to its former condition of density or even to a condition of increased density. In favorable soil, however, the effect may last several years.

It has been found that fine-grained soils under continued cultivation tend to become more dense; and as they become

increasingly dense, more of the rain is lost as runoff. Bradfield says in a paper on soil conservation (*Jour. Am. Soc. Agr.*, vol. 29, February, 1937):

> In many cases from 25 to 30 per cent more soil is crammed into a cubic foot than was present in the virgin soil. This has reduced porosity, especially the volume of larger pores through which water penetrated readily and through which the soil received the necessary ventilation. As a result of these changes in structure, root development is hampered, the storage capacity of the soil for water is reduced, flood hazard is increased, and the damage from . . . droughts is magnified.

Beneficial effects of cultivation are likely to be more lasting with respect to rainfall intake in those soils which have a relatively low content of sticky or plastic clay. On the other hand, loose, porous sands obviously are not likely to be especially benefited by cultivation, since they generally are too open in the first place, do not fracture very much, and tend to settle back rapidly to their former condition, except under the drifting effect of wind.

Cultivation sometimes tends to reduce water intake by closing the larger of the natural openings into the soil by crushing or filling the cavities. And subsoiling plastic clays and wet land is of doubtful value.

Effect of Organic Matter on Intake of Rainfall. When coarse organic matter is incorporated with a soil, the porosity remains high for a comparatively long period, depending chiefly on the rate of decomposition of the material.

Similar effects on soil porosity are produced as the result of crop rotations, turning under crop residues, growing grasses and legumes, and using other methods that increase the soil supply or organic matter. Work at the West Virginia Agricultural Experiment Station (Browning, *Soil Sci. Soc. America Proc.*, vol. 2, 1937) has indicated that soils receiving such treatments ordinarily are characterized by a higher content of rela-

tively large *aggregates of soil* particles (soil granules or clusters) than of small aggregates. This means essentially that soils of coarsely aggregated structure have larger pores and, consequently, greater water-intake capacity as well as greater absorption capacity, as a rule. As compared with land under continuous cultivation to clean-tilled crops, infiltration measurements have shown generally a higher rate of intake for those areas which have been efficiently managed with respect to maintenance of the organic supply, as under good pasture practice or good crop rotations.

Effect of Muddy Water on Intake of Rainfall. The infiltration rate of a soil is profoundly affected by the muddiness of surface water. Clear water penetrates a soil much more rapidly than muddy water. This, as already explained, is because the suspended material of muddy water tends to filter out as surface water enters the soil openings, choking them and impeding downward movement. Soils in a *flocculated* (aggregated) condition are much less subject to this sealing effect of muddy infiltration than those whose particles are separated as individual grains. This is because such granular material, as well as the material of soil in good condition of *tilth* (sponginess) or of favorable organic matter content, generally does not enter so readily into suspension to produce muddy surface water as *nongranular* soil or soil deficient in humus. *Turbidity* (degree of muddiness) is also of much less importance or altogether lacking on areas having a dense cover of vegetation. Water flowing from thickly grassed areas, for example, is frequently essentially clear following heavy rains, whereas that from adjacent cultivated land is almost always muddy in some degree.

Lowdermilk found (*Internat. Cong. Forestry Proc.,* 1929) that muddy water percolates through the soils tested at about one-tenth the rate of clear water. The soil in suspension filtered

out at the surface to form a thin layer of fine-textured material, silt and clay, which determined subsequent rate of intake irrespective of the capacity of the material below the surface for percolation.

This experiment establishes one of the most fundamental facts in land use. To a considerable degree, it explains why clearing land of its natural cover of vegetation and its cultivation create a special hazard in the acceleration of soil erosion under agricultural use. The natural cover prevents the formation of *soil suspensions* (water with floating particles of soil) by rainwater at the surface (by binding the soil and by maintaining a granular condition unfavorable to detachment of the particles). Thus, the water remains clear, and the rate of infiltration is maintained at the natural capacity of the undisturbed soil to take in rainfall. But bare soil surfaces produce muddy suspensions readily under the impact of rain, and such suspensions, as already pointed out, tend to seal the surface, thereby reducing the rate of intake of water into a soil.

The muddiness of runoff from bluegrass and alfalfa grown on dark prairie loessial soil of good organic content (Marshall silt loam), at the soil and water conservation experiment station near Clarinda, Iowa, averaged under the same rainfall (over a period of 3½ years) less than 0.2 pound of suspended soil per cubic foot as against a turbidity of more than 4.0 pounds per cubic foot, or twenty times as much, in runoff from the same kind of land on which corn was grown continuously.

Methods for Increasing Intake of Rainfall. Intake of rainfall can be increased in a variety of practical ways. For example, soils peculiarly subject to surface crusting following rains shed water at relatively rapid rates if the crust remains unbroken until the next rain. Accordingly, breaking of the hardened or compact surface by cultivation is likely to have considerable effect, temporarily at any rate, toward increased intake of water.

Subsoiling under certain conditions, particularly in soils having clay sublayers susceptible to fracturing, also speeds up the rate of intake.

The total amount of water entering a soil is governed to a considerable degree by the time available for infiltration. Therefore, if water can be made to move slowly rather than rapidly across the land or if it is impounded on the surface, the amount of intake is thereby greatly increased. A variety of feasible methods are available for retarding or, on moderately sloping land, even preventing runoff. One of the most satisfactory is the use of vegetation in complete or partial coverage of the ground. As already pointed out, both runoff and erosion from sloping land densely covered with such vegetation as grass, clover, or alfalfa are much less than from comparable land under cultivation. Measurements show that surface discharge of water from a cultivated crop is frequently more than 2½ times and, in some instances, several hundred times that from land under such cover as clover, alfalfa, bluegrass, or Bermuda grass.

Other effective methods of retarding surface runoff and increasing intake of rainfall, such as incorporation of organic matter with the soil, protection of the surface with vegetative mulch, contour furrowing and cultivation, terracing, and strip cropping, are described elsewhere.

Need for Increased Soil Storage of Rainfall. Increased infiltration of rainfall on upland areas, aside from its powerful effect in reducing runoff and erosion, is important throughout the country generally because of the dependence of plants on soil water reserves in times of drought. Even in the humid regions, deficiencies in soil moisture are the cause of seasonal crop deterioration nearly every year in many upland localities. The Atlantic seaboard has a rainfall of 40 to 50 inches; yet during July and August, pastures frequently deteriorate or give

out and field crops are sometimes seriously damaged because of moisture shortage. Recent advances in soil and water conservation techniques have shown that such deficiency can be made up to a considerable degree through water conservation practices, with particular attention to storage of water in the soil during periods of rain.

Increased conservation of rainfall by practical soil-storage methods probably is the most promising opportunity for improvement in the treatment of cultivated uplands, not only because of the storage of needed water for crop use but because the very methods by which such storage is achieved are among the most effective methods for reducing erosion.

Relative losses of rainfall, as runoff, percolation, evaporation, and transpiration, as measured for cropped and uncropped land at the Clarinda, Iowa, Soil and Water Conservation Experiment Station are shown in Table 6.

TABLE 6. SUMMARY OF RUNOFF, AMOUNT OF RAINFALL PASSING BELOW ROOT ZONE, AND VAPOR LOSS[1] ON A PERMEABLE SOIL (MARSHALL SILT LOAM) IN INCHES[2]

Type of loss	Not manured		Manured	
	Bare (no crop)	Cropped to corn	Bare (no crop)	Cropped to corn
Runoff	29.47	19.16	21.27	13.20
Amount passing below root zone	14.16	5.77	23.51	10.63
Vapor loss	58.78	77.48	57.63	78.58

[1] Evaporation only from bare ground; evaporation and transpiration from corn ground.

[2] Under cropped and uncropped conditions, with and without manurial treatments, at Clarinda, Iowa. (Total precipitation 102.41 in. for period of $3\frac{2}{3}$ years.)

It is noted here that on bare ground (no crop), not manured, approximately 14 inches of a total precipitation of a little more

than 102 inches (14 per cent) passed below the root zone (3 feet below surface), nearly 59 inches (57 per cent) evaporated, and 29 inches (about 29 per cent) was lost as runoff. At the same time, only 5.7 inches passed below the root zone in the untreated corn area, 19 inches was lost immediately as runoff, and 77 inches disappeared as evaporation and transpiration.

From the corresponding manured areas, the runoff from bare ground was 8 inches less than from the unmanured bare area, and approximately 8 inches more passed below the root zone. The loss by evaporation remained substantially the same. At the same time, the manured cornland lost only 13.2 inches as runoff, and only 10.63 inches passed below the root zone. Evaporation and transpiration were about the same from both the manured and the unmanured corn areas.

These excessive losses of water from a soil of such good permeability as that tested at the Clarinda station (Marshall silt loam), coupled with an annual precipitation of only about 30 inches, show the importance of making the greatest possible use of all feasible measures for increasing the penetration of rainfall. The loss by runoff and evaporation of more than 88 per cent of the total precipitation from bare ground is a striking indication of what is taking place, probably rather generally, on unplowed fallow; and what happens on bare ground is an indication that the water losses from cultivated fields are extremely excessive.

If it is assumed that evaporation accounts for half the vapor loss from the unmanured corn plot shown in Table 6, then runoff and evaporation are responsible for the loss of approximately 58 per cent of the total precipitation.

Clearly, the practical farmer cannot afford to lose much water as runoff, since it is a total loss and produces erosion besides. That part of the rainfall which penetrates below the root zone may have a beneficial effect on its way down if it

does not go too fast; in addition, it may favorably replenish the underground water supply.

It has been shown that those practical soil treatments which increase penetration of water into the ground do not cause increased losses by evaporation. Conservation of rainfall, then, is equivalent to increasing the rainfall, in so far as plants are concerned. In general, therefore, it is important to increase the penetration of rainfall into the body of the soil by whatever practicable means available, for two reasons: (1) consequent reduction of runoff and erosion, (2) increase of available water for plant growth.

Although different soils differ markedly in respect to the amount and rate at which they take in water, it has been shown that even refractory and relatively impermeable soils can be improved vastly in this respect by such treatments as the incorporation of organic matter, maintenance of a vegetative mulch at the surface, good cropping practices, and good tillage.

Practical measures for conserving water lost as runoff are given in subsequent chapters.

Questions

1. What becomes of rainfall after contact with the land?
2. What is water intake? Absorbed water? Runoff?
3. What is water of percolation? Water table?
4. What physical features of soil affect water storage capacity?
5. How much water can soils store?
6. How do variations in soil openings affect water intake? What is meant by soil granularity?
7. Under what conditions are soils saturated by rainfall?
8. What effect does tillage have on intake of rainfall?
9. How does muddy water affect intake?
10. How does dense vegetation prevent muddying of rainfall?
11. What is the effect of organic matter on intake? On absorption?
12. How do soils become compact under cultivation?

13. What determines availability of soil water?
14. What is "bone-dry" soil?
15. How does soil cracking affect availability of moisture?
16. Does ordinary cultivation increase or decrease intake?
17. How does evaporation affect the supply of soil moisture?
18. How much of the rainfall can be lost by evaporation and runoff?
19. How does time affect intake of rainfall?
20. Give example of artificial means for measuring water intake.
21. Of what importance are practical measures for increasing rainfall intake? Absorption?
22. Why is subsoiling of plastic clay and wet soil inadvisable?

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CHAPTER 8

A National Program of Soil Conservation

PRESENTING:

Soil Conservation Defined
Soil and Water Conservation Demonstrations
Soil Conservation Districts
Work of Other U.S.D.A. Agencies
- Forest Service
- Agricultural Adjustment Agency
- Farm Security Administration
- Federal Extension Service
- Bureau of Entomology and Plant Quarantine
- Bureau of Plant Industry, Soils, and Agricultural Engineering
- Rural Electrification Administration
- Farm Credit Administration
- Bureau of Agricultural Economics

Work of U.S.D.I. Agencies
- Fish and Wildlife Service
- Bureau of Reclamation
- General Land Office
- Geological Survey
- Office of Indian Affairs
- Grazing Service
- National Park Service

Other Agencies
The Future

Soil Conservation Defined. Stated in simplest terms, conservation of the soil is a matter of using land efficiently under a farming system that safeguards it from erosion. Some land is too steep to be farmed; some soils erode too freely to be culti-

vated; some regions are climatically unsuited to intensive agriculture; and so on. Proper use and protection of the land, in other words, is governed by certain physical factors. When it is used without regard for these factors, the processes of waste begin. If this wastage is permitted to continue, the land becomes poor and eventually useless for the sustenance of man.

Specifically, soil conservation is the use of land, within the limits of economic practicability, according to its capabilities (the way nature made the land) and its needs (as affected by man's use of the land) in order to keep it permanently productive. All adaptable means required to achieve this permanent productivity of the soil constitute the tools of conservation, whether they are used singly or in infinite combination.

More specifically, soil conservation consists of safeguarding all kinds of useful land—and nearly all varieties of land are useful for some purpose—against impoverishment or depletion caused by

1. Excessive soil removal—erosion.
2. Deposition of the products of erosion.
3. Exhaustion of plant nutrients through leaching, excessive cropping, or overgrazing.
4. Accumulation of toxic salts.
5. Burning (in the case of organic soil—peat).
6. Waterlogging (inadequate drainage).
7. Improper cultivation.
8. Any type of improper use or failure to protect the land from soil loss or impairment of its productiveness.

Soil conservation is accomplished by

1. Using adaptable conservation practices and engineering structures to prevent or control soil erosion and the deposition of the products of erosion.
2. Using improved tillage, mulching, and cropping practices to conserve rainfall.

3. Using rainfall, organic matter, manure, fertilizers, lime, etc. with maximum efficiency.

4. Draining and flooding to prevent the accumulation of toxic salts.

5. Draining to prevent waterlogging.

6. Flooding, controlling the water table, and using other adaptable means to prevent the burning of peat lands.

7. Changing from unwise cultivation of shallow, highly erodible, or otherwise unfavorable land to the planting of grass, trees, or other protective cover to achieve better use and better protection of the land; governing the intensity of grazing range and pasture to retain sufficient vegetative cover to conserve rainfall, maintain the forage stand, and prevent soil erosion.

8. Draining, irrigating, clearing, or otherwise improving previously unproductive land to fit it for practical, productive use and thereby to encourage a shift to safer, less intensive uses on near-by, highly erodible or otherwise unfavorable land (as by substituting rich drained bottomland for poor, highly erodible hillsides).

9. Irrigating and increasing the production of supplemental feed on adaptable areas (if available) of ranching enterprises where the dry-land grazing areas are incapable of producing sufficient year-round feed to sustain profitable or safe (from the standpoint of the soil) ranching units.

10. Increasing diversification in cropping and livestock production, including pasture improvement, in the interest of better adjustment, if needed, of farming operations to the land.

11. Utilization for wildlife of odd corners, borders, and areas of land not usable for ordinary cropping, pasture, or forestry purposes.

Soil conservation is, therefore, the scientific use of land.

Certain factors of an economic and social character, however, also influence the use of land. Men who farm the land

must make a living. Normally, this is their most realistic and immediate concern. Economic need is a powerful factor in determining how they use the land. In some sections of the country, men are attempting a type of agriculture, raising beef, for example, that cannot normally be carried out economically on small farms; in other instances, farms may be too large for sound operation with available facilities; elsewhere, the tenure system frequently impedes proper use of the land. As they affect the immediate interests of the individual operator, therefore, economic and social influences of this kind are, unfortunately, a part of the problem of soil conservation that must be given due consideration in any program for safeguarding the land against the consequences of unbridled erosion.

It is also necessary to recognize, with genuine concern, the breed of land exploiters whose sole aim in entering the field of agriculture is to make the greatest possible number of dollars in the shortest possible time, regardless of what the consequences are to the land. Many thousands of acres have been unnecessarily ruined because their owners have wilfully used them too hard. With full realization of their actions, they have bartered land for dollars. These are truly exploiters of land rather than normal farmers and really patriotic citizens.

Consequently, from the standpoint of common sense, national action to conserve the soil resource must not only deal with soil erosion and related physical facts but also cope with the complex economic and social considerations that affect the use of land. Worth remembering, nevertheless, is the unalterable physical fact that no matter what the immediate economic needs and social influences may be, if land is allowed to wash or blow to a condition of permanent uselessness, the people of the America of tomorrow can have no possible share in the productivity that nature originally stored in such land for the benefit of mankind.

The ultimate objective of national action—a land resource carefully safeguarded to sustain fully the present and future national economy—will be reached only when the principles of soil conservation and proper use of the land have been accepted and put into practice by agriculture as a whole.

But agriculture as a whole is based on the activities of millions of individuals. The land is owned and used by many men. They enjoy the rights and privileges of private ownership or lease under the American system. National action to conserve soil must be generated by these millions of land users. If they are active and willing participants in such a movement, the land will endure; otherwise it will fail. Responsibility of government to help its citizens in conservation, in the interest of the public welfare, is a matter of common sense. But it seems best for national action of this kind to spring from people on the land and, to a large extent, be advanced by them as individuals and groups, with the help of government and support of the general public. Congress, through a series of recent acts, has erected the framework of a comprehensive-action program (a program of actual work on the land) looking to the conservation of the nation's soil resources. This program is being carried on cooperatively by Federal and state agencies, farmers, and ranchers.

The current work of the Soil Conservation Service, established under the Soil Conservation Act of 1935, constitutes a national comprehensive-action program to conserve and utilize properly soil and water resources. Other agencies, at the same time, are administering other acts of Congress directed toward the correction or alleviation of certain economic and social maladjustments that contribute to land abuse. The work of these agencies complements in various ways and degrees the work of the Soil Conservation Service toward effective action bearing on the physical, economic, and social aspects of the land and people.

The program of the Soil Conservation Service of the United States Department of Agriculture follows several lines of action having a common ultimate goal of better conservation of soil and water, more efficient use of land, and a more abundant life for the people of the country, both urban and rural, now and for all time. The lines of action are as follows:

I. *Soil Erosion Control and Conservation of Rainfall.* This is the program authorized by the Soil Conservation Act of 1935 (*Public* No. 46, 74th Congress) and designed to conserve basic soil and water resources by applying sound and adaptable conservation practices to all farm, forest, and grazing land vulnerable to soil erosion by water or wind. Among other activities, action in this program involves (1) research to determine the character, causes, and effects of soil erosion and to develop or improve practical measures for erosion control and conservation of rainfall; (2) surveys to determine the facts needed in planning and prosecuting erosion-control and water conservation work; (3) cooperation with local soil conservation groups (Soil Conservation Districts) through technical assistance and work on the land; (4) cooperation with Federal, state, and local agencies in soil and water conservation, land-use adjustment, and related fields, formed under the authority of state law; (5) dissemination of information regarding erosion and its control through the normal media of public communication.

II. *Submarginal Land Purchase.* This program, authorized under Title III of the Bankhead-Jones Farm Tenant Act of 1937, is designed to bring about improvements and corrections in aggravated problems of land ownership and settlement, uneconomic size of holdings, unsound type of farming, inadequate farm income, high costs of public services in sparsely settled communities, and tax delinquency, which frequently must be dealt with before proper use of the land and the wel-

fare of landowners and operators and the community can be established on a permanently satisfactory basis.

Action under this program involves (1) the purchase of land of low productivity or land not primarily suited to cultivation, (2) improvement of purchased areas for more adaptable uses, (3) cooperation with local groups of farmers and with public agencies in furthering programs of better land use, such as pasture and range management, water development, flood control, fire prevention, rural zoning, and improvement of woodland and wildlife conditions.

III. *Flood Control.* This program was authorized by the Flood Control Act of 1936 and supplemental legislation and designed to reduce the hazard of floods to human life and property through treatment of the watersheds from which floodwaters originate as well as the waterways themselves.

The activities of the United States Department of Agriculture under this program are correlated with those of the Corps of Engineers of the War Department and involve water-flow retardation, soil erosion prevention, and reduction of siltation that complement and supplement the construction program of the corps having to do chiefly with large-scale engineering projects.

The determination of flood-control measures to be applied to a particular watershed is made through a two-step study: (1) a preliminary investigation of the seriousness of the flood problem and the economic feasibility of control or improvement by adaptable land measures; (2) a detailed survey to determine the applicable measures and practices and the benefits to be derived from watershed treatment.

Actual installation of watershed-protection work on an approved flood-control project becomes the responsibility of the Soil Conservation Service in those areas predominantly in farms and of the Forest Service in those areas primarily in forests.

IV. *Drainage and Irrigation.* Activities of the Soil Conservation Service in the drainage and irrigation phases of the national soil and water conservation program involve (1) the development of efficient and economical methods of draining and irrigating agricultural land as a part of the soil conservation research program carried out in cooperation with agricultural experiment stations; (2) technical assistance, on request, to soil conservation districts, drainage districts, and other responsible groups and agencies (*a*) to insure adequate consideration of both farm and group drainage and irrigation problems in the development of conservation plans and (*b*) to help in the repair, rehabilitation, and establishment of drainage and small irrigation works.

Soil and Water Conservation Demonstrations. Between September, 1933 and 1943, demonstrations in soil and water conservation began to be established in many of the important farming and grazing sections of the United States having a serious erosion problem. (The original intent was to have such a demonstration within at least 50 miles of most farmers. This was not fully achieved, but individual farm demonstrations helped to some extent toward carrying out the program.)

The area selected as a demonstration site usually was a drainage basin in which the soils, topography, climate, and cropping and grazing systems were closely similar to those found on farms and ranges in a large surrounding territory and where the farming and grazing methods needed to control erosion and conserve rainfall were applicable to the whole problem area. The method employed in these demonstrations was to help land operators with the actual job of controlling erosion, conserving rainfall, and making necessary changes in the pattern of land use; crop and range specialists, soil specialists, agricultural engineers, tree specialists, wildlife experts, and other technicians combined their skills to attack the problem

simultaneously along several fronts. They planned protective measures to fit the needs of every parcel of land of important size (from the farm standpoint); and in the application of these measures to the land, special care was taken so to co-ordinate them that each measure supplemented the others in such a way that what was done on a farm or in a field contributed, where possible, to the protection of adjacent fields or farms as well as to more distant downstream areas.

In setting up a demonstration, the first step was to obtain a base map of the entire project area. If such a map was not already available, one was made with aerial photographs as the base. Then, careful farm-by-farm survey was made in order to obtain detailed facts about soil erosion conditions, slopes, current land use, and other pertinent features and superimpose these directly on the base map. From this basic information, *land-capability* maps were drawn up, showing the productivity capacity and protection needs of every distinct tract of land on each entire farm or ranch where work was to be done.

With such information as a guide, the conservationists were able to draw up individual farm plans for each farmer in the area interested in adopting a conservation system. Cropping changes, improved tillage methods, protection planting, and structural devices were discussed with the farmer on the ground. Every step for every field, pasture, wood lot, and tract of idle ground was considered on the basis of need, adaptability, practicability, economic feasibility, and physical relationships with adjacent lands.

If the farmer decided to adopt the conservation plan finally developed, a cooperative working arrangement was agreed on and the job of putting the farm plan into effect proceeded. The farmer and conservation specialists worked together in a mutually helpful manner until the plan was fully applied to the

land. Labor, power, materials, and seed were contributed by the farmer to the extent of his ability; the specialists laid out the work, drew up the necessary structural specifications, provided whatever labor and materials the farmer was unable to supply, and furnished suitable planting material for lands taken out of cultivation because of their highly erodible character. There was no sitting down by a table and telling farmers what to do; the Soil Conservation Service specialists worked with farmers out on their lands.

An example showing the major steps in this coordinated plan of land treatment in a representative demonstration area will partly illustrate the application of a soil conservation program to a single watershed.

The Green Creek Soil and Water Conservation Project in Erath County, Texas, comprised approximately 30,000 acres and was fairly representative of the *West Cross Timbers* section, which covers approximately 7 million acres in Texas and an additional large area in Oklahoma. The soils are predominantly sandy loam with moderately stiff clay subsoil; the topography ranges from undulating to moderately rolling. For the most part, farming has been carried on for only about 45 years.

The number of farms in the county decreased by 28 per cent between 1910 and 1935, according to the census. The value of farms in the county, including land and buildings, decreased by 54 per cent between 1920 and 1935, and farm population decreased by 33 per cent between 1910 and 1930.

Surveys in this watershed in 1935 disclosed that 13 per cent of the area had been essentially ruined for cultivation by erosion and that approximately 50 per cent of the topsoil of all the cultivated land had been washed or blown away when the project started. Many farmers were attempting to control erosion by terracing; some were doing nothing to defend their wasting fields. Of 4,082 acres of terraced land on 103 farms in

the project area at the time when the work began, only 1.6 per cent of the terraces were satisfactory and only 3 per cent could be rebuilt to function properly (98.4 per cent of all the terrace work on these 4,082 acres was inefficient, showing how necessary it is to do a technical job with the aid of skilled technicians). Of the cultivated land terraced prior to 1935, a total of 29 per cent had been retired from cultivation or abandoned by the owners and operators because of erosion damage. An additional 18 per cent of this terraced land was retired subsequently when the 103 terraced farms joined in cooperative working arrangements with the Soil Conservation Service.

Under these arrangements, an integrated 17-point program was employed. It involved

1. Detailed farm surveys (to ascertain the physical and economic conditions) of 217 farms, comprising 29,990 acres and including 132 farms actually cooperating in the watershed program.

2. Joint preparation of detailed working plans for each farm by conservation specialists and cooperating farmers, on the basis of the physical facts and of the economic conditions on these farms.

3. Application of the following soil and water conservation measures to meet the diverse needs of the various land and farming conditions of the 132 cooperating farmers (these measures were not all used on any single farm):

a. Terracing of slopes ranging up to 5 per cent.

b. Crop rotation.

c. Cover crops for seasonal protection of fields.

d. Retirement of severely eroded cultivated land to the permanent protection of grass or trees.

e. Contour cultivation.

f. Planting critically erodible areas to feed and cover plants for rehabilitation of wildlife.

g. Control of gullies, chiefly with grass.

h. Control of terrace outlets with grass.

i. Construction of small grassed channel ways to carry water discharged from terraces safely downhill.

j. Development of broad meadow strips for safe disposal of excess runoff from terraced and contoured fields.

k. Pasture development by contour furrowing and reseeding.

l. Pasture improvement through rotation grazing, reduced grazing, and mixed grazing.

m. Consolidation of small fields into larger fields adaptable to contour cultivation, stripping, terracing, and other treatment necessary for adequate protection of soil and proper conservation of rainfall.

n. Construction of small reservoirs for continuous supply of stock water.

o. Field stripping to check wind erosion.

The mere enumeration of these major steps reveals little of the manner in which they were employed. It fails to indicate how one measure was used to support another or how protection of one field provided protection to adjacent fields. However, since the establishment of these measures within the watershed, observations by farmers, businessmen, newsmen, farm journalists, and technicians reveal that the conservation work not only has very largely checked erosion but has stored so much of the rainfall in the soil that floods along the principal stream (Green Creek) have been greatly reduced.

Similar results were obtained generally in most of the demonstration areas throughout the country. The adoption of a scientific system of land conservation and use, involving the integrated application of a variety of applicable conservation measures, has generally secured the soil against erosion. Simultaneously, flood crests have been lowered and the silt content of the water reduced along many streams. In the Great Plains,

practically all the rain falling on thousands of properly treated fields and pastures has been held on the ground to be absorbed, furnishing moisture for a cover of vegetation adequate to protect the soil from both wind and water erosion. Moreover, in a number of instances, much or all of the rain that normally ran to waste through roadside ditches, gullies, and other drains has been directed to useful purposes by diversion into fields and pastures.

There is ample evidence in most of the demonstration areas to show that lands that a short time ago were declining steadily, along with the agriculture on them and the people, are now well safeguarded from the impoverishing effects of erosion and that most of the farms are moving steadily in the direction of increased yields per acre—and increased opportunity, security, and prosperity.

Benefits Today of the Green Creek Work. Green Creek used to overflow its banks and do considerable damage to adjoining fields two or three times a year, according to the testimony of local farmers. That was before conservation measures were installed on most of the farms within the drainage basin. The creek still overflows occasionally following exceptionally heavy rains but not nearly so often now. Conservation measures have increased crop yields on most of the farms of the area, and there is greater diversification. Peanuts are being grown in place of cotton on many farms, and dairying and poultry raising have largely increased. Protective, soil-building winter cover crops, as rye, vetch, and winter peas, have come into common use. Previously these crops were seldom grown. The use of crop residues as a protective mulch is becoming a standard practice.

With the increase in dairy cattle in the Green Creek watershed has come increased interest in both permanent and temporary pasture crops. Permanent pastures are being managed for

maximum production of desirable grasses, and growth of supplemental summer and winter crops for pasture has helped raise the average annual net income from livestock. Some of the severely eroded lands have been successfully developed for pasture.

Soil Conservation Districts. One of the most important developments of recent years in the field of soil conservation has been the emergence of the soil conservation district as a mechanism for cooperative conservation action on a local scale by the users of the land themselves. Through these districts, established under state law, the facilities of government, both state and Federal, can be brought most effectively into play in response to the direct demand of farmers and ranchers. Even more important, the districts represent a significant development in bringing democratic processes to bear upon the problems of the land.

The rapid growth of soil conservation districts since the first district was organized (Brown Creek Soil Conservation District, Aug. 4, 1937) is significant, moreover, of a trend toward the determination of the people to safeguard permanently the most basic asset of the nation—productive soil. Forty-seven states have enacted legislation authorizing the formation of these local cooperative soil conservation organizations. As of mid-June, 1946, more than 1,600 districts had been formed, covering an aggregate area of some 875 million acres of land and including around 3,900,000 farmers. By invitation, the Soil Conservation Service was cooperating with about 1,440 of these districts, covering more than 784 million acres.

The function of the district is to develop and carry out a comprehensive program of effective soil and water conservation through sound use and proper treatment of all the land within its boundaries. The district itself may undertake to

carry out the work, or it may request the assistance of the Soil Conservation Service and other agencies.

The program drawn up by a district embracing five counties in north-central Georgia will illustrate the part that these local agencies are now taking in the national soil and water conservation program.

The declared objectives of the program of this Georgia district are, as given in its annual report covering operations for 1944, in general, to "enable farmers to raise and maintain a suitable standard of living and to perpetuate agricultural resources within the district." More specifically, they are (1) to bring about the adoption of necessary practices for the conservation of soil and water resources, (2) to make necessary adjustments in the use of land, directed at an increased income for farmers, and (3) to develop such necessary land-management practices as will provide for the efficient utilization of extra feed and pasture resources resulting from the realignment of farm cropping systems.

In approaching these objectives, the district proposed complete soil conservation treatment of all farms with such sound practices as strip cropping, terracing, contouring, cover cropping, crop rotations, and woodland and pasture improvement. It proposed also a number of readjustments in the use of land, including an increase in total cropland of approximately 12,500 acres, an increase in pasture land of approximately 7,500 acres, a decrease in woodland pasture of approximately 8,000 acres, a decrease in idle land of about 60,000 acres, reforestation of some 30,000 acres of eroding land used for "row" crops, purchase and development of approximately 200,000 acres of submarginal land, rehabilitation of some 2,900 low-income farmers through loans by the Farm Security Administration, protection and improvement of 26,000 acres of farm woodland, and development of food and cover for wildlife on all farms.

Into this district, at the specific request of the district supervisors, the Soil Conservation Service carried the facilities of a major public action program. It had the authority approved by the Congress and administrative branches of the Federal government and the supervisors of the districts to assist in planning and applying soil and water conservation measures on individual farms, in establishing good woodland- and pasture-management practices, in reforesting or regrassing croplands retired from cultivation, in purchasing the areas of submarginal land recommended for permanent retirement by the district, in draining waterlogged lands, and so on. Through alliance with the district and at the request of individual farmers, the Service was enabled not only to readjust practices on individual farms but to fit these practices and needed realignments in the use of land to the larger pattern of desirable land use in the district as a whole.

A large share of the activities of the Soil Conservation Service are now being carried out in direct cooperation with soil conservation districts (most of its funds are specifically appropriated for that purpose). As rapidly as new districts are formed in the various states, the Service endeavors to cooperate with them to the extent of available resources where the districts request such cooperation. In this way, the Service is able to assist most effectively the large groups of farmers who are cooperatively engaged in the prevention of soil wastage on a large scale and whose holdings and operations represent all land within a complete watershed or other defined area.

The operations carried on by the Soil Conservation Service in districts follow the same principles of soil and water conservation, through the application of the coordinated method of land treatment according to adaptability and economic feasibility, as were employed in the demonstration projects.

Work of Other U.S.D.A. Agencies. In addition to the Soil Conservation Service, a number of other agencies of the Federal government and the states are engaged in programs that relate in some measure to the wise use of land and the conservation of soil and water. Space permits only brief reference to the activities of these agencies. All of them have issued publications explaining their programs and the results obtained. Such agencies in the United States Department of Agriculture are as follows:

Forest Service. Among the major functions of the Forest Service are the protection, development, and administration in the public interest of the federally owned national forest system and its resources and products and research in problems involving protection, development, and continuous use of these resources and products.

The national forests are located in various parts of the Appalachians from New Hampshire to Georgia, around the Great Lakes, in the Southern Pine Belt, and on the slopes of the Rockies, Cascades, the Sierra Nevada, and the Coast Ranges between Canada and Mexico. According to the late F. A. Silcox, former chief of the Forest Service (*U. S. Forest Service Ann. Rept.,* 1938):

> . . . the national forest system . . . as of June 30, 1938, comprised 175,238,168 acres of federally owned lands. Established irrespective of State boundaries, these public properties are distinct from national parks in that they are administered on a multiple-use basis, with renewal of all their resources and values.
>
> Today's national forests offer striking contrasts between civilization and wilderness, industrial activities and pastoral, material values and spiritual ones. More than 1,280 million feet of timber was harvested from them, under provisions that assure continuity of the forest stand, in the fiscal year 1938. They already provide a living for almost a million people and recreation for 30 million each year; are home and refuge for most of our remaining big game; include some 70,000 miles of fish-

ing streams and more than 3,500 developed public camp-grounds; furnish forage for more than 6,857,000 domestic livestock; help prevent floods and erosion; and provide domestic water for 6 million city people. They have a public transportation system that includes more than 138,000 miles of highways and roads and 153,000 miles of trails. Gross receipts from the national forests in the fiscal year 1938 were $4,671,133, with $1,178,883 returned to the States.

Increasing numbers of stockmen who use portions of the national forests for grazing recognize the fact that conservation management means a lower death loss among livestock (especially in times of drought), increased lamb and calf crops, better animals, better wool, and higher net return. Irrigationists now recognize their interest in the national forest lands, from which they derive much of their water supply. And townspeople, at least indirectly dependent on the welfare of forest, range, and farming industries, are becoming increasingly aware of their responsibilities in the management and protection of public forests.

In some of its activities, such as fire-prevention operations in areas near national forests, the Forest Service cooperates with the state forestry agencies.

Agricultural Adjustment Agency (AAA). This agency is responsible for implementing desirable shifts in national farm production by commodities and for making conservation- and production-incentive payments to farmers. After national commodity production goals are broken down by states and after state committees have broken down state goals by counties, a farm-to-farm canvass is conducted by county and community committeemen, when each farmer is informed of the national situation and goals and of the part that production on his farm can play. To a certain degree, he is guided in growing his share of the needed crops and livestock and in choosing the soil and water conservation practices that he should adopt for maxi-

mum production. Farmers earn payments under the AAA program (made either in cash or in materials and services) for the successful accomplishment of these practices. AAA committees administer marketing quotas when they are in effect for any particular crop and likewise are in charge of field administration of the sugar program, the crop-insurance program, and the commodity-storage and loan program.

The Soil Conservation Service cooperates with the AAA in its soil conservation work.

Farm Security Administration. This agency has the task of helping needy and low-income farm families to become self-supporting. A majority of these families probably are victims of ill-fated attempts to farm on poor land or land impoverished by erosion or severe cropping, on farm units of inadequate size, or under unstable tenure arrangements and one-crop systems. Perhaps a combination of all these adverse factors along with low prices and high costs contributes to subsistence farming.

Many poor farmers have been helped to get a fresh start through the FSA's rehabilitation program. Under this program, low-income families unable to obtain adequate credit from any other source are given assistance in working out sound farm-management plans and are loaned the funds necessary to put the plans into effect.

The FSA advances funds to needy farm families upon the basis of farm- and home-management plans. It assists in the adjustment of farm debts and provides for a program of long-term loans to farm tenants in order to assist them in becoming owners.

The Soil Conservation Service cooperates with the FSA in preparing adequate farm plans for control and prevention of erosion and for conservation of rainfall.

Federal Extension Service. The Extension Service, as an educational agency, aids in making available to farmers and

ranchers the results of agricultural research. It coordinates the extension activities of the bureaus of the department and cooperates with state extension agencies. State extension agencies cooperate with various Federal and other agencies in the educational aspects of agricultural activities. The local work is handled chiefly through county agricultural agents and home demonstration agents.

Bureau of Entomology and Plant Quarantine. This agency studies insects, gives advice on how to control or use them, seeks to prevent the spread of insect and plant diseases, and enforces Federal plant-quarantine laws. The program of the bureau covers the study of chemicals and other substances useful for combating insect pests, cooperation with states and local agencies in controlling outbreaks of insect and plant-disease scourges, and inspection of import and export plant products.

Bureau of Plant Industry, Soils, and Agricultural Engineering. This bureau is primarily concerned with research work involved in the breeding of new strains or varieties of plants that are resistant to disease, insects, and other deterrents, the introduction of foreign plants of indicated advantages to the United States, cultural techniques having to do with the quality and yield of crops, and improvements in the preservation and transportation of perishable plant products.

Rural Electrification Administration. This organization promotes the extension of electric power lines to farms, rural communities, and other nonprofit organizations through loans made to local groups organized under state laws.

Farm Credit Administration. This agency provides credit to farmers and stockmen on both long-term and short-term bases. Operation is through (1) loans from Federal land banks to local farm loan associations, (2) production credit corporations and local associations, and (3) district banks which make loans to farmer cooperatives. The Farm Credit Administration

also makes emergency crop and feed loans and charters and supervises Federal credit unions, which are cooperative, thrift, and loan associations formed by urban and rural groups.

Bureau of Agricultural Economics. This bureau provides statistical information on production, demand, supply, consumption, prices, marketing, transportation, and other useful farm data.

Work of U.S.D.I. Agencies. Among the agencies in the Department of the Interior concerned with various spheres of land use are the following:

Fish and Wildlife Service. This service had its inception in 1885 as the Branch of Economic Ornithology in the Division of Entomology, United States Department of Agriculture. In the half century since C. Hart Merriam gathered together a handful of workers to investigate the relations of birds to agriculture, it has evolved from a purely research institution into a large organization of research and action. The agency was transferred to the Department of the Interior July 1, 1939.

The service conducts research in relation to all types of wildlife and carries on extensive activities in the field of wildlife conservation through the development and operation of refuges, lakes, and fish hatcheries. It administers the Migratory Bird Treaty Act, the Migratory Bird Conservation Act, and other similar acts as well as laws regulating the interstate transportation of wildlife. It purchases, develops, and administers lands for the establishment of wildlife refuges. The service promotes trade and commerce in fish products, administers the fur seal herd in Alaska, and regulates hunting and trapping in that territory.

Bureau of Reclamation. The bureau constructs and maintains Federal irrigation works for the storage, diversion, and development of water for the reclamation and use of arid and semiarid lands. In short, it brings water to dry lands. It is

responsible for the operation and maintenance of facilities for the delivery of water to Federal reclamation projects. The bureau is responsible for power development at some of the larger reservoirs.

General Land Office. This office is responsible for the survey, classification, management, leasing, and distribution of the lands of the public domain. It handles grants for railways and other rights of way and easements across public domain lands. In national forests, it executes laws relating to surveying, prospecting, appropriating, entering, patenting, and granting of rights of way. (Combined, July, 1946, with Grazing Service as Bureau of Land Management.)

Geological Survey. This agency conducts research and carries on surveys in the field of geological and mineralogical activities and underground water supplies. It makes topographic surveys and supervises the technical aspects of mineral leasing on lands in which the title to the mineral resources remains in the United States. It also classifies public-domain lands as to their mineral and power value.

Office of Indian Affairs. This office manages all Indian affairs on government-controlled lands of the Indian reservations. This includes the organization of Indian tribes, Indian credit associations, Indian relief, education, health activities, etc. The office purchases and manages land for Indian use and promotes forestry, irrigation, soil conservation, and the construction and maintenance of roads and bridges.

Grazing Service. The primary objectives of the Grazing Service of the Department of the Interior, established under the Taylor Grazing Act of 1934, are, according to that act, to regulate grazing on organized range lands of the public domain in order to prevent overgrazing and soil deterioration; to provide for their orderly use, improvement, and development; and to stabilize the livestock industry dependent on the public range.

In cooperation with local associations of stockmen, state land officials, and various other agencies, the Grazing Service conducts range surveys to determine the carrying capacity and proper seasonal use of the land, prescribes rules and regulations for range use, issues permits for such use through district advisory boards made up of representatives elected by the stockmen, and engages in operations designed to rehabilitate, improve, and preserve the public range land included within established districts.

National Park Service. The service is responsible for the development and management of the national park system, including national monument and historic site projects.

Other Agencies. Other agencies concerned with various phases of land use are as follows:

Office of the Chief of Engineers. This office, in the War Department, in addition to its military responsibilities, is charged with the supervision of all Federal investigations and improvements for navigation, flood control, power development, and other purposes and of rivers and harbors and other waterways except as otherwise specifically provided by act of Congress. The duties include the execution of works ordered by Congress for the improvement of rivers and harbors and other waterways for navigation, flood control, and power development; examinations and surveys for navigation, flood control, power development, oceanic canals, and other purposes.

Tennessee Valley Authority. This corporation was set up under *Public* No. 17, 1933, to improve the navigability and to provide for the flood control of the Tennessee River, to provide for reforestation and the proper use of marginal lands in the Tennessee Valley, to provide for the agricultural and industrial development of the valley, to provide for the national defense by operation of government properties at and near Muscle Shoals in the state of Alabama, and "for other purposes."

Vocational Education, United States Office of Education. This agency promotes vocational education in agriculture, trades and industry, home economics, etc. It cooperates with Federal and state agencies in the educational aspects of various agricultural activities, including the training of both present and prospective farmers in soil and water conservation.

State Agencies. State agricultural colleges—experiment stations, extension services, etc.—vocational training services, planning boards, and conservation, forestry, and agricultural departments are actively engaged in educational, research, planning, and to some extent action programs bearing directly or indirectly on the problem of soil and water conservation.

In a number of states, the highway departments, soil conservation districts, the Soil Conservation Service, and the Bureau of Public Roads are cooperating for the control of erosion along public highways. This work is contributing also to highway beautification and traffic safety.

As soil conservation work progresses, the role of state extension services becomes increasingly important. With their staffs of county agricultural agents, they are in an excellent position to stimulate and assist in the widespread adoption of conservation measures. In parts of the country, state extension services have long recommended certain individual practices, such as terracing, for erosion control. Currently, however, more and more states are advocating erosion control through the coordinated use of all adaptable conservation measures to meet the needs of the various kinds of land. To present their recommendations more effectively, a number of states through their extension departments, working with the Soil Conservation Service, have established cooperative demonstrations for erosion control and water conservation in the farming sections.

Staff members of state agricultural colleges and other educational and research institutions are giving more time to the

study of different phases of the erosion problem, including its economic and sociological aspects. Information of this type, essential to the practical adoption of conservation methods, is being developed on both a localized and state-wide basis. Wherever possible, the Soil Conservation Service is cooperating in this work.

State experiment stations also are playing an important part in the furtherance of soil conservation. In cooperation with the Soil Conservation Service, they are participating in the development of fundamental facts bearing on the erosion process, on the improvement of present methods of control, on discovery of new methods, and on various other aspects of the erosion problem requiring research. The relation of erosion to such factors as land type, soil condition, topography, and the intensity of precipitation is being given particular attention. Other institutions also are cooperating with the Service in these research activities.

In connection with water conservation and utilization, which are completely inseparable from soil conservation, some of the geological agencies are providing certain kinds of helpful information pertaining especially to underground water supplies and the relation of the substrata to drainage and water-storage operations.

In a number of aspects, the objectives of various state agencies are closely related to and the work allied with several of the Federal agencies briefly described above.

The Future. Unless the United States goes ahead vigorously, persistently, and speedily to defend and conserve the soil and to make far-reaching adjustments in its complex land economy, national decadence lies ahead. The nation must continue to capitalize on experience and to advance through research. From the standpoint of the country's soil resource alone, the need for action is now clear enough. Failure to act in the past

already has caused the essential ruin or serious impoverishment of some 282 million acres of farm and grazing land. Now erosion is active on an additional 775 million acres. Many people still do not yet fully understand the deep significance of this waste or realize the hardships that it has caused by lowering thousands of land users virtually to the level of bankrupt farming on bankrupt land, with its attendant discouragement and inertia. To date, the soil and economic implications of this single aspect of the erosion problem have not been fully probed and appraised.

There is no longer a question of the need for coping with these evils. There is no longer a question as to whether or not the nation can cope with them. We know that we can. Millions of acres already have been effectively anchored against erosion through the proper employment of practical farm and ranch measures and practices. New and practical conservation measures are being developed continually through research and experience on the land. Many of our economic and social difficulties on the land are beginning to be solved. We are moving constantly ahead, though not yet with sufficient speed.

It should be remembered that today's necessity for public action is the outgrowth of yesterday's failure to look more carefully to our land. Looking back is easy; but foresight during the last century, when our present land-use picture was in the making, would have produced a different result. Today, we are simply retracing our steps across the land in an effort to correct past mistakes in the interest of the future.

Never for a moment should the nation overlook the fact that safeguarding productive soil is national defense, that the sooner adequate protection is provided the cheaper and easier it will be to complete the job, and that thousands of families could live in some degree of sufficiency and contentment on the land that

has been permitted to waste away every year under the impact of uncontrolled erosion.

Questions

1. What is soil conservation?
2. How does soil conservation affect the individual operator?
3. What obligation has the individual land user toward soil conservation?
4. What responsibility has the government in soil conservation?
5. How can government best help in getting soil conservation accomplished?
6. How does economic need affect land use?
7. What was the first Soil Conservation Act? When enacted?
8. What briefly is the program of the Soil Conservation Service? The Agricultural Adjustment Agency? The Forest Service? The Bureau of Reclamation?
9. What are the objectives of the submarginal land purchase program?
10. How were soil and water demonstrations conducted? Give an example.
11. What are the objectives of Soil Conservation Districts? How are they formed? Operated?
12. Give an example of how a Federal agency cooperates with a Soil Conservation District. A state agency.
13. What work is done by the Grazing Service? The National Park Service? The General Land Office?
14. What is the primary objective of the Forest Service?
15. What contributions do geological agencies make in soil conservation?

References

See publications of the agencies named for details of their objectives, programs, etc.

CHAPTER 9

Planning for Conservation of Soil and Water

PRESENTING:

Basic Principles of Conservation Farming
Coordinated Plan of Erosion Control
Tools for Conservation
Making the Farm Plan
Land Capability
Group Meetings

Since the beginning of the present national program for conservation of soil and water, two cardinal principles have dominated and guided the work. Some called these principles idealistic and impractical, and some apparently failed to grasp their significance.

Basic Principles of Conservation Farming. The first of these basic guiding principles was at the outset and is today as follows: *Effective prevention and control of soil erosion and adequate conservation of rainfall in a field, on a farm or ranch, over a watershed, or on any other unit or parcel of land require the use and treatment of all the various kinds of land comprising that area in accordance with the individual needs and adaptabilities of each different area having any important extent.*

Like any precise statement of a rule, however, this principle requires qualification.

Obviously, the use and treatment of a given area of land must be determined not only by its physical characteristics but also by such considerations as available facilities, implements, power,

and financial means and even by the preference of the farmer, his ability to learn and willingness to try new methods, and his inclinations. In other words, the treatment must fit not only the needs and adaptabilities of the land but the facilities and adaptability of the farmer as well.

Another qualification of the general principle is that each distinct parcel of land to be treated should be considered in any pertinent physical relation that it may have to an adjacent or neighboring tract or to the entire farm, ranch, or watershed. The use and treatment of one area should, wherever possible, provide as much protection as may be practicable for adjacent areas. The management of lands on higher elevations should be determined in relation to downslope and downstream lands. Outlets for surface runoff should be located with proper regard to the effect that discharging water and suspended soil material will have on adjoining lands.

The areas devoted to crops, grazing, and forest, respectively, should constitute sound economic units or as nearly so as may be practicable.

The second guiding principle has been from the beginning and still is the following: *Efficient application of conservation measures to land requires the technician's presence out on the land.* Accordingly, the conservationist does not deal with farmers and ranchers in a closed room or seek to accomplish conservation by giving them bulletins or asking them to fill out score cards; he goes with the farmer or rancher out into his fields, pastures, timbered areas, and odd lots of idle land, working with him on his land. Knowing the principal kinds of land in the locality and the conditions of erosion, the soil conservationist and the farmer cooperatively draw up a plan that fits these main differences and meets the conservation needs of the farm or ranch.

Coordinated Plan of Erosion Control. This work of soil conservation calls for a new kind of technician—the soil conservationist—a man with experience in appraising land from the standpoint of soil and water conservation needs and a man who knows also how to make a farm plan for conservation and how to apply the provisions of the plan to the proper parts of a farm. The technician takes into consideration all the pertinent factors—kind of land and needs of the land with respect to prevention of erosion, maintenance of soil fertility while continuing in production, conservation of rainfall, etc.—and treats the farm accordingly. Thus, the tools of the land specialist, agronomist, forester, engineer, biologist, and others are coordinated and applied to whole farms as a single, complete implement of conservation.

This is new in agriculture, and it is working with an amazing degree of success. It is scientific use of land, replacing the old, haphazard, wasteful methods of land use that have needlessly brought so many farms and so many farmers and communities to grief.

Farmer Reaction. From the first, farmers have liked this kind of work and have wanted more of it. This is unmistakably shown in the development of more than 1,600 soil conservation districts, wherein the coordinated tool of soil conservation is being used very successfully and where there is a continuous flow of farmer requests for technically guided work.

To carry out such a coordinated program of land treatment, farm by farm, on a nation-wide scale requires a great deal of basic information for the most efficient blueprinting and planning of each farm. There are many kinds of soils occupying varied slopes and subject to different intensities of rainfall and erosion. These land varieties are adapted to varied crops and cropping practices.

It is probably safe to say that no two parcels of land are identical. For this reason, each field—even each important part of a field, pasture, or wood lot—requires its own particular set of conservation measures. Conservation specialists have found that in some localities, each farm, each ranch is a special problem within itself—a special job resulting primarily from the particular environment and requiring specialized treatment.

Tools for Conservation. The soil conservationist has at his command many different types of control measures for handling different types of problems. Unfortunately, however, effective conservation practices have not yet been developed for all the numerous problems and combinations of problems relating to the contrasting agricultural lands and practices of the nation. It is necessary, therefore, to seek constantly for cheaper, sounder, and more efficient ways of conserving soil and water.

Soil conservation is the youngest of the major agricultural sciences. And so, from the very start, the work has been supported by a program of research seeking new and better implements for getting the job done.

Where vegetative and mechanical conservation measures have been efficiently joined and applied as part of a complete conservation treatment for the land, the results on intertilled cropland probably have averaged about 85 to 90 per cent effective. There are numerous instances, of course, where the results are nearly 100 per cent effective.

Rapidly now, more and more is being learned about the science of soil conservation, both through research and through practical farm experience.

Throughout the country, conservation-farming technicians and other agriculturists are striving to develop and perfect as rapidly as possible the new field methods, structures, and machinery precisely adaptable to the erosion control and production needs of each varying agricultural locality. New crops are

being brought into use, and old ones extended. Steadily, all this work is taking the form of a new agriculture—one based primarily on soil conservation farming methods. And to date our progress with it is pacing the rest of the world.

For example, the perennial lespedezas and kudzu have wrought profound changes in the use of much severely eroded land in many parts of the Southern states. Lands that a little while ago were considered too poor or too steep or too erodible to farm—even areas that were so gullied that they could not be plowed at all—are now producing excellent hay or grazing with these valuable crops. And the crops are holding the soil, retarding runoff, reducing the effects of silting, and raising farm income by reason of higher yields per acre and by putting all the land on the farm to some kind of productive use.

Turning soil upside down, according to the traditional way of plowing (which has been one of the main functions of the turning, or moldboard, plow) is not everywhere the wisest way to plow. It buries the vegetative material, including grain stubble, cornstalks, grass, and legumes, as well as weeds or other protective material anywhere from 6 to 12 inches underground and turns fresh, loose earth to the top where it is exposed to the ravages of wind and rain (see Chap. 19, Stubble-mulch Farming).

Conservation farming puts first things first by attending to the needs of the land—by seeing to it that the starting-off place, the base, is put into rewarding condition and kept that way by using it correctly and then safeguarding it with practical conservation farm methods. Any other approach, no matter what it may be, always has and always must lead eventually to agricultural disaster. Such are the physical facts involved.

If there were a simple standardized remedy for the ills of the land that could be applied indiscriminately, the job of soil conservation would be comparatively easy. But there is as

much variety in erosion and the performance of water and wind as in the landscape of the country. Control methods that work wonders in the gully-torn cotton country of the old Piedmont plantation section of the Southeast may do more harm than good on the dusty wheatlands of the Great Plains, and vice versa. Even on neighboring farms, as already noted, land problems are almost never completely identical. And in those localities where much of the precipitation is in the form of snow, special measures are required for safeguarding farm and range land. For this reason, the soil and water conservation program must be sufficiently flexible to meet the varying conditions and circumstances.

The specific land treatments used and recommended by soil conservationists may therefore vary from one valley to the next, from farm to farm, and even from field to field. Before any work is done, each farm or ranch is carefully analyzed, both as a piece of land and as a business enterprise.

In making the physical analysis to determine productivity needs, requisite protection, etc., conservation field men carefully note on the ground, as already indicated, the exact lay of the land, the quality of the soil, the degree of erosion damage, and the prevailing erosion hazards on every acre of every field, wood lot, pasture, and idle area. These conservation technicians, working closely with the farmers, determine as accurately as possible which lands can be cultivated under good farm practices without excessive loss of soil and rainfall; which lands need the protection afforded by special crop arrangements, special tillage practices, or structural installations; and which ones require a permanent cover of trees and grass and the management practices necessary to maintain that protective vegetation.

Making the Farm Plan. The next step in soil conservation is to work out with the farmer a farm plan or blueprint for

guiding practical operation, based on the ground information acquired.

In some cases, this new arrangement may not entirely fit the farmer's pocketbook. It may call for more hay crops than he actually needs or can sell and not enough potatoes or corn; it may involve other changes that he cannot afford to make. If so, it is not a good arrangement in a practical sense, and it must be adjusted, if possible, to meet family needs, farm needs, and market opportunities. Purely from the conservation standpoint, however, the farm arrangement based on physical land analysis is ideal. The closer the farmer can approach it and still make a good living the more stable and productive his land will be and the surer his income, over the long run.

Land Capability. Farm plans are based largely on the capability of the land. The ground information necessary for determining the capability of the various kinds of land found on a farm is preferably collected in advance of drawing up the final farm plan. This advance information relates to such characteristics of the land as slope, erosion, susceptibility to overflow, stoniness, salinity, presence of high water table, land use, soil texture and depth, moisture relationship, and fertility of the soil. These are the more important physical facts needed as a guide to placing conservation effectively on the land.

The information goes to the farmer in a very simple form, usually as a sketch on an aerial photograph. The sketch shows no more than eight land classes, called *land-capability* classes (Fig. 43), which range from land of such favorable quality and condition as to require no special treatment for proper cultivation and adequate protection against erosion through land requiring a variety of treatments for efficient and safe cultivation to land that should never be cultivated under any circumstances.

The following are brief definitions of the eight capability groupings:

Land Suitable for Cultivation:

Class I. Land of good productivity practically free of erosion and suitable for cultivation without special practices; some areas may need to be fitted for cultivation, as by clearing or simple drainage.

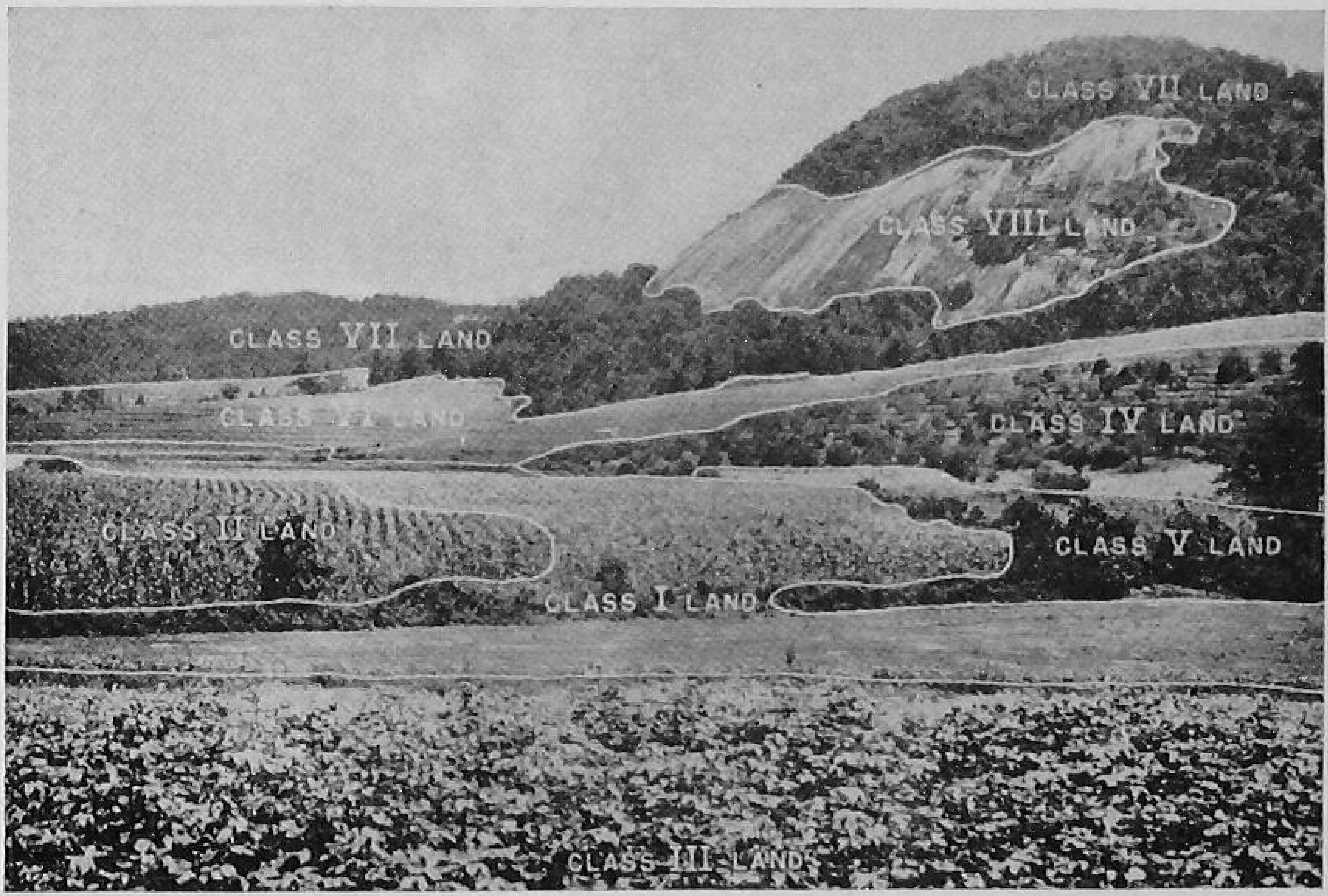

Fig. 43.—Illustration of the eight land-use capability classes.

Class II. Land of moderate to good productivity suitable for cultivation with ordinary or simple practices to prevent erosion or effect satisfactory drainage, as by contouring, growing protective cover crops, and carrying out rather easy drainage operations, as with small ditches, where needed.

Class III. Land of moderate to good productivity suitable for cultivation with intensive practices, such as terracing, strip cropping, heavy fertilization, and installation of extensive drainage facilities.

Land Suitable for Limited Cultivation:

Class IV. Land of moderate productivity suitable chiefly for pasture and hay because of steepness of slope, with occasional use for row crops. When it is cultivated, intensive erosion-prevention practices usually are required.

Land Not Suitable for Cultivation:

Class V. Land not suitable for cultivation but useful for grazing or forest with normal precautions to insure sustained use.

Class VI. Land not suitable for cultivation but suitable for grazing or the growing of trees with strict precautions for sustained use.

Class VII. Land not suitable for cultivation but suitable for grazing or forestry when used with extreme care to prevent erosion.

Class VIII. Land not suitable for cultivation, grazing, or forestry, although it may have some value for wildlife. This land ordinarily is extremely rough, stony, sandy, wet, or susceptible to severe erosion.

With a land-capability map of a farm in his hands, the conservation technician is best prepared to take up with a farmer the cooperative preparation of a conservation farming plan for his farm, as indicated in the foregoing.

Walking over the farm together, they come to a common understanding of the different classes of land and their distribution over the farm. The farmer outlines in a general way what he grows, what he is interested in doing, what livestock he keeps, what machinery he has, when he wants to start on the job of conservation farming, and so on. Steep or unproductive croplands may be earmarked for a permanent cover of grass or trees; farm forests may be planned where grass is not paying out (Fig. 44) or is failing to hold the soil; gullied areas may be

turned into grass-covered waterways or farm sanctuaries for animals and birds or valuable pastures of kudzu (Fig. 45).

They may find that fences need to be relocated in order to rearrange fields for efficient use of the different classes of land.

Fig. 44.—Three-year-old pines planted on steep poor land—Capability Class VII—near Spring Grove, Minn. This land formerly was cultivated but was too steep for successful crop production. This is wise land use through proper adjustment of plants to the physical environment. (Trees planted by Soil Conservation Service.)

The acreage and the location of land required to produce the feed needed for the farm animals is decided on as well as that required to grow the cash crops that the farmer wants to sell. The acreages for the latter crops will be found in the areas shown as Classes I, II, and III.

Following this, the best arrangements of fields are worked out to allow for crop rotations and other methods for handling the land properly. If there is any Class IV land on the farm, it should be used, generally, for permanent meadow or hay or

long rotations including these. Land for pasture and farm wood lots will ordinarily be taken out of Capability Classes V, VI, and VII. Practices for erosion control that need to be adopted are discussed at those locations on the farm where they

Fig. 45.—Grazing kudzu on land that was taken out of cultivation because of steepness and susceptibility to erosion—Capability Class VI—and put into permanent pasture as a part of the conservation farming program for this Virginia farm. Cultivated portion in background is land of Capability Class III.

belong, so that the farmer can better visualize the farm plan and know precisely what each proposal means. At the conclusion of the planning work, the end product is a new arrangement of fields, pastures, meadows, and woods that safeguards the soil and fits the land as nature made it—and as man upset it. This constitutes an adjustment in land use most nearly meeting the requirements of the physical environment (Fig. 46). Together with the adapted conservation practices, it makes up the complete farm plan for soil and water conserva-

tion. Under such a plan, soil conservation is not just an incidental bit of the mechanics of farming; it becomes part and parcel of the whole business of making a living from the land and is the only way by which we may have permanently pro-

Fig. 46.—A farm completely treated for conservation. Terracing, strip cropping, crop rotations on the contour basis, and cover crops, gully control, retirement of steeper land from cultivation to trees and kudzu are all practiced on this South Carolina Piedmont farm to fit the needs and adaptabilities of the different kinds of land. (Work by Soil Conservation Service.)

ductive land for a permanent agriculture to support a permanent nation.

In the great livestock range areas, soil conservation takes a somewhat different form from that in the farming regions. Normally, less emphasis is placed on basic shifts in land use, and stress is more along the line of protection and improvement of grass through careful management of water and livestock (Fig. 47). Fundamentally, however, the conservation plan on the western ranch is like that on an eastern farm. It is a combi-

nation of good land use, appropriate land management, and adequate soil defense, based as nearly as conditions permit on the inherent needs and adaptabilities as well as the man-induced conditions of every single acre.

Fig. 47.—Ranch management in the Cross-Timbers country near central part of Oklahoma. In addition to installation of stock-water pond, the grass has been improved by contour ridging and reseeding with little bluestem.

Group Meetings. Recently, land-capability maps have been used in farmer group meetings to save some of the time that otherwise would be required to cover every part of the farm before work begins. This is not a substitute for technicians and farmers eventually inspecting the farm together but a method of saving time by getting work under way. The land capabilities and control practices, crop rotations, etc., can be explained at one time to a dozen or more farmers in a group meeting. Often each farmer is given a map of his farm and asked to go over his place with the view of doing preliminary

planning on his own. Many farmers do a surprisingly good job of planning after they have attended two or three meetings. Not only is the technician's time saved in helping develop the final farm plan, but the average farmer becomes more enthusiastic about the whole thing when he is brought into the actual constructive job of developing a good, applicable plan for soil conservation and improvement.

Questions

1. What are the cardinal principles of soil conservation farming?
2. What is meant by the coordinated attack on the erosion problem? Name some of the tools of conservation.
3. Why is it important that soil conservationists work with farmers out in their fields and pastures?
4. Why should the national program of soil and water conservation be supported by a continuing program of research?
5. Why can there be no short cuts to soil conservation?
6. How are soil conservation farm plans made? Define land capabilities.
7. What, besides the physical conditions of the land, affects the development of farm plans for conservation of soil and water?
8. Why is each farm or ranch a special problem?
9. Name five items of basic physical information about land needed for conservation farming.
10. How can severely eroded land be brought into productive use?
11. How can a farmer help with preliminary farm planning?
12. Why must soil conservation plans have flexibility?
13. How is soil erosion affected by climate? By the moldboard plow?
14. How can the farmer get an early start on developing his farm plan?

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CHAPTER 10

Use of Vegetation in Soil and Water Conservation

PRESENTING:

- Crop Rotation
- Strip Cropping
- Protective Cover Cropping
- Groups of Plants Useful for Soil Conservation, Pastures, etc.
- Legumes for Meadows or Protective Cover
- Some Overlooked Vegetation Useful for Erosion Control

Land completely covered with vegetation, whether grass, legumes, shrubs, or trees, is in ideal condition for resistance to erosion and absorption of rainfall. When white men came to America, most of the country was covered in varying density with forest, grass, bush growth, or desert vegetation. Under such conditions, erosion was generally limited to a normal, harmless rate. The accelerated erosion of comparatively recent years is, as already shown, the product of wholesale land denudation. It is the result of removing forests, plowing up the prairies and plains, and overgrazing the ranges. Although it is not possible to restore original conditions of vegetation and at the same time maintain the nation's agricultural economy, measures taken to conserve soil and water must be patterned, as far as possible, after nature's own methods of soil defense. This means a much more extensive use of close-growing vegetation in our farm operations and the maintenance of a protective cover of vegetation, or a vegetative mulch, on as much of the land as possible for as much of the year as possible.

There are several reasons why close-growing vegetation and vegetative debris are highly effective in checking soil and water losses. In the first place, such cover serves to reduce or eliminate the direct impact of rain on the soil surface. Wherever a drop of rain strikes bare soil, particles are agitated and loosened and the finer ones are thrown into suspension. By sheltering the ground surface with vegetation or vegetative debris, this first step in soil wastage is controlled. Then, too, the speed of water flowing over the surface is checked by the numerous stems of a dense stand of vegetation or by the vegetal litter left or placed on the surface. This reduction in the speed of runoff greatly decreases its power to pick up and carry off soil particles, while allowing more time for the water to penetrate the earth. Finally, an increase in the soil's supply of organic matter by (1) root growth and decay, especially in the instance of a permanent cover, or (2) the incorporation of green manure or other adaptable vegetable material favors water absorption by improving the water-holding capacity of the soil. Vegetative debris, such as crop residues and straw, has an important place in checking both wind and water erosion and increasing the water-holding capacity of the soil. And too, the roots of plants have a binding effect on the soil as well as a favorable effect on its structure.

These principles are basic; they underlie any attempt to conserve soil and water by the use of close-growing vegetation. The particular vegetative methods used in any given situation, however, will depend (1) on local farm needs, slope, kind of soil, and physical condition of the soil; (2) on adaptability of crops to local conditions, including climate; and (3) on the need of vegetation to support or complement engineering methods of conservation.

Some vegetative methods of erosion control are applicable to nearly all regions, whereas others, such as the use of winter

cover crops and range vegetation, are more serviceable in some parts of the country than in others. In no region, however, should one method be depended on to the exclusion of all others. All are interrelated; and even on a single farm, two or more methods may need to be used. For instance, crop rotation alone may be used where this will assure control, but other parts of the same farm may require strip cropping or a combination of strip cropping and crop rotation. All these methods may be used with or without terraces, depending largely on slope and kind of soil.

The principal methods by which herbaceous vegetation is used to insure conservation of soil and water are as follows: crop rotation, strip cropping, pasture and meadow improvement, and the growing of crops for protective cover and green manure. Vegetation is also used in gully control, in the stabilization of field waterways and diversion ditches, in windbreaks, in buffer strips, in field "edges" for protection of game, and in stabilizing range land against wind and water erosion while increasing the grazing capacity.

Crop Rotation. Crop rotation is generally defined as a more or less regularly recurrent succession of different crops on a single piece of land. The crops used are commonly a cultivated crop, a small grain, and a grass, a legume, or a legume-grass mixture. Of these, the cultivated crop exposes the soil to maximum erosion, small grain allows less erosion, and the grass or legume-grass crop effectively controls erosion during the period of its life and lessens it for some time thereafter. When a cultivated crop follows sod, soil loss is usually reduced below what it would have been had one cultivated crop succeeded another. The net result for the rotation period is almost invariably a reduced soil and water loss (see Rates of Erosion and Runoff, Chap. 5).

Purpose and Advantages. Primarily, crops are rotated in order to maintain productivity and yields. Crop rotation systematizes farming, saves labor, and helps to control weeds, insects, and plant diseases; it aids in maintaining soil organic matter and nitrogen, lessens soil loss through erosion, and often "conditions" soil (perhaps by a process of sanitation or correction of toxic conditions).

Types of Rotations. Crop rotations vary with the land, economic condition, cropping systems, and specializations of different farming regions. The 3-year rotation of a cultivated crop followed by small grain and then grass or a legume-grass mixture, however, may be considered as more or less basic. This can be modified in various ways by dropping one crop to make a 2-year rotation or by having one of the crops on the same field for more than 1 year, thus lengthening the rotation to 4, 5, or even more years. When grass or a legume or a mixture of the two forms part of the rotation, the cultivated crop usually follows immediately and the small grain serves as a companion crop for the next stand of grass or legume.

Of various approved rotations, the following will serve as examples: In the northeastern Appalachian and New England area[1] a good many farmers use a 2-year rotation of crimson clover-potatoes or a 3-year rotation of oats-red clover-potatoes. In the more southerly part of the same area, a corn-wheat-clover rotation is common. In the southern Appalachian region, a rotation of (1) corn with cowpeas, (2) small grain, (3) lespedeza, and (4) cotton with a winter legume provides for three legume crops in 4 years. Where cotton is not grown, a 3-year rotation of 2 years of corn followed by meadow may be used. In the central prairie and eastern timbered border region, in parts of which the practice of crop rotation is well established,

[1] See Bennett, H. H.: "Soil Conservation," McGraw-Hill Book Company, Inc., for location and description of this and other regions.

an approved common rotation includes corn, small grain, and meadow, with the last sometimes left for 1 or 2 years as pasture. In the Ozark Highlands, corn interplanted with cowpeas is often followed by cotton, and this by small grain and then cowpeas.

In parts of the Great Plains region, corn is replaced by sorghums and wheat occupies the ground for a longer period, so that a typical rotation includes grain sorghums, oats and sweetclover mixed, sweetclover alone, and finally wheat for 2 years.

The principles to be followed in a soil-saving rotation are to reduce the time that the land is occupied by a cultivated crop as much as the economic situation of the farm will permit, increase as much as practicable the time it is covered by a legume or a grass, and lessen the amount of tillage required. The same principle is applicable when another crop is used for soil protection. For example, in western Kentucky a rotation of tobacco 1 year followed by 2 years of strawberries may meet the soil-saving requirements. In this rotation, the ground is protected by the strawberries. Such rotations may cover several fields, with each crop occupying a full field each year; or they may be combined with strip cropping, the crops being rotated from strip to strip in a single field. In the "yellow" (or "'bright") cigarette tobacco district of Southeastern United States, grass (even weeds in some instances) has been reported as improving yields and reducing erosion without the harmful effect on the quality of the leaf that the growers have often complained of when legumes are used in the rotation.

The best practice to use will depend very largely on the slope, soil, and the operational requirements of the farm.

Rotations on Contour. On sloping land, other measures will be needed to supplement crop rotations if soil and water losses

are to be reduced to a minimum. Of these measures, contour cultivation, terracing, contour strip cropping, and the use of cover crops are the most important.

The flexibility of a strip-cropping system makes it possible to meet practically any crop or livestock problem through proper arrangement of the strips, even to the extent of grouping in a single field, for purposes of convenience (to economize on hauling, grazing, etc.), those crops which fit well together in a strip-cropping system. For example, close-growing contour strips of small grains alternating with legumes, legume-grass mixtures, or grass alone may be used in those instances where it is undesirable to have all crops of a rotation in one field at the same time. Such an arrangement would, for example, meet the requirements of the livestock farmer who desires to graze fields after the grain is cut without setting up to protect the still unharvested crops, as corn or beans, temporary fences that might interfere with grazing in the same field. Many farmers are, however, finding it practicable and advantageous to make use of strip cropping on a regular rotation basis by using portable electric fences to allow for grazing individual strips without damage to unharvested crops.

Rotation of Crops Saves Soil. From the standpoint of soil and water conservation, the value of crop rotations must be measured by comparative soil and water losses, as from plots with and without rotation. A number of experimental studies show that when crops are grown in good rotation, the soil loss from a given field is less for the rotated area than it would have been had the land remained continuously in a cultivated crop.

At Guthrie, Okla., for example, records from a 3-year rotation of cotton, wheat, and sweetclover, covering two rotations, or a 6-year period, show the following average annual losses of rainfall and soil from comparable areas:

	Runoff, per cent of precipitation	Average annual soil loss, tons per acre
Continuous cotton	14.2	24.2
Cotton in rotation	12.7	14.3
Wheat in rotation	13.9	1.7
Sweetclover in rotation	8.0	0.5
Average of rotation	11.5	5.5

Similar results were obtained at La Crosse, Wis. The records from a 3-year rotation of corn, barley, and clover follow, expressed as average annual runoff in percentage of total rainfall and tons of soil lost annually per acre.

	Runoff, per cent of precipitation	Average annual soil loss, tons per acre
Continuous corn	21.0	89.0
Corn in rotation	16.3	53.8
Barley in rotation	13.1	21.4
Clover in rotation	7.2	0.9
Average for rotation	12.0	25.0

It is evident that the soil loss from corn following clover in the rotation is less than where corn is grown continuously, also, that the soil loss during the entire rotation occurs mainly while the field is in a cultivated crop. This emphasizes the need for additional protective measures during the year when a cultivated crop occupies the land.

Crop Rotation Maintains Yields. Not only does a good rotation reduce soil and water loss, but it serves to maintain yields.

Hence, the practice is a profitable one for the farmer to adopt regardless of its value in saving soil and moisture.

For example, at the soil conservation experiment station at Temple, Tex., the yields of lint cotton following Hubam clover, in a cotton-Hubam rotation, averaged 177 pounds of lint per acre (total of 343 pounds) above the yield of cotton following cotton (166 pounds) over a 3-year period.

Plants Used in Crop Rotations. Except in parts of the Great Plains, in the Palouse country, and occasionally elsewhere, a crop rotation ordinarily includes at least one cultivated crop. This may be corn, cotton, tobacco, or potatoes. Another will be a small-grain crop, the choice of which will depend on local adaptability and economic needs. Wheat, barley, rye, oats, or sorghum may be used, depending on the severity of winter conditions and the individual farmer's requirements. A third crop should, wherever possible, be a biennial or perennial legume, a grass, or a mixture of a grass and legume.

Under some conditions, the small-grain crop may be omitted, as in northern Maine where a rotation of potatoes followed by crimson clover is sometimes used. In the Palouse, the cultivated crop is dropped, and the rotation may begin with 2 years of sweetclover and grass followed by several years of small grain. Also, in parts of Kansas, the rotation may be 3 years of wheat followed by oats and sweetclover.

Strip Cropping. Water flowing down an unprotected slope gathers both volume and speed as it moves; consequently, the erosive power of runoff often increases with the length of the slope over which it flows, especially where the surface is of even declivity. In effect, the practice of strip cropping, as with terracing, divides a long slope into a series of shorter ones. Its value is based on the principle that anything that checks the flow of water will reduce its capacity both to pick up soil particles and to carry them along in suspension. Strips of close-

growing crops planted across the slope not only will decrease runoff and soil loss on that part of the field which they occupy but will act to (1) desilt the water flowing over them from cultivated parts of the field above (Fig. 48) and (2) reduce the

Fig. 48.—Strip-cropped field in Dallas County, Texas. Contour strips of oats 36 feet wide (light-colored bands) separate strips of cotton and corn (dark bands) 108 feet wide.

rate of flow enough to give considerable protection to the clean-cultivated strip below.

Strip cropping, then, is a system under which ordinary farm crops are planted in relatively narrow strips, across the slope of the land, and so arranged that the strips of nonerosion-resistant crops are always separated by strips of close-growing, erosion-resistant crops.

In *contour strip cropping,* the strips are planted on the contour, at right angles to the natural direction of the slope. In *field strip cropping,* the strips are laid out parallel to one an-

other across the general slope, not necessarily on the exact contour. *Wind strip cropping* involves the planting of regular farm crops in straight parallel strips at right angles to the direction of the prevailing winds, without regard to the contour.

The most important of the strip-cropping practices in controlling erosion and conserving water is contour strip cropping.

Contour Strip Cropping. Contour strip cropping is conducted on the level across the slope, instead of up and down hill, in order to interrupt the flow of water and make it penetrate the soil. Strip cropping on the contour, combined with terracing where necessary, has proved a very practical means for conserving soil and water on a vast area of cultivated land, especially on slopes of comparatively gentle gradient (generally less than 5 to 6 per cent).

Strip cropping is employed with or without terraces. In long rotations including 3 years or more of grass, terracing is not so important in a strip-cropped field. Where stripping is used without terraces, care must be taken to follow the contour as closely as possible. Irregularities of relief, however, sometimes make it necessary, in order to avoid too many "point" rows (short rows), to keep the rows parallel, even though this may call for moderate deviation from the contour. If the soil is fairly permeable and the deviation is slight and continues for only a short distance (100 feet or less), such departure from the contour is not likely to cause serious damage. No great deviation from the contour should be permitted (seldom more than 2 per cent), however, unless provision is made for grassed waterways to conduct the accumulated water through the succeeding strips to the foot of the slope. Where conservation of rainfall is an important objective, across-slope operations (strip cropping, listing, and terracing) should be maintained as nearly on the contour as may be practicable.

Laying out a strip-cropping system in fields that have been level terraced is relatively simple because the contours are permanently marked by the terraces. The width of the strips can be adjusted easily to the terrace interval.

The establishment of a strip-cropping system for an entire farm may or may not necessitate complete rearrangement of the farm plan. Where this is unavoidable, proper adjustments in the plan may call for careful consideration of such physical conditions as variation in relief, runoff concentration points, size and nature of the drainage area above each field, length of slope, soil condition from place to place, crops grown in the rotations, and the kind of farm machinery employed.

In laying out a field for contour strip farming, the first step is to decide how wide every contour strip should be at its narrowest point. Let us suppose that the minimum width selected is 75 feet, or five times the width cultivated by one round with a four-row cultivator. The next step is to establish a point for locating the contour line that will form the lower boundary of the first strip, which should be at the top of the slope. This point is established by measuring along the steepest part of the slope (with chain or steel tape) 75 feet downhill from the upper boundary of the field. A line through this point is then drawn along the contour to the edges of the field by use of a level. The procedure is repeated until the entire field is laid out in contour strips (each of which will be narrowest where its slope is steepest). In planting row crops in contour strips, operations should proceed on the contour from the edges of each strip to the center. Unless the slope is uneven, some rows near the center of a strip may extend only part way across the field (short rows).

Where there are a considerable number of strips, the following method is sometimes employed: The line to be used as a base in laying off strips should be on the contour and so located that the maximum number of strips can be measured from it

both up and down the slope. Such base line may mark either the upper or the lower boundary of one of the strips of protective thick-growing crops, or it may be used for the center line. If the surface is very uneven, a single base line usually will serve to lay off only two or three strips. Under such conditions, additional base lines will be necessary where more strips are needed. This often will necessitate the use of a *correction strip* between the last two even-width strips used regularly for row (intertilled) crops. Such strips are of irregular width and so placed between contour plantings of cultivated crops as to permit the cultivated strips to be of uniform width.

In establishing a cultivated strip upward from the base line, the rows are laid out parallel to the base line until the point of maximum allowable departure from the true contour is reached. From this point, it becomes necessary to go farther up the slope to the next established base line and lay off rows parallel to the downward side until the deviation from the true contour is again reached.

Several methods are used in locating strips of thick crops on terraced fields. They can be placed on the whole terrace interval, extending from terrace ridge to terrace ridge, or they can be located so as to straddle the terraces with approximately half of the strip above and half below the ridge. These basic procedures may be modified to suit special soil conditions or unusual crop requirements. For example, a portion of the terrace interval may be seeded to erosion-resistant crops and part to row crops; or the terrace ridge may be seeded to a close-growing crop that will serve to strengthen the structure. Where the variety of crops grown in rotation permits, row crops can be planted in strips that straddle alternate terrace ridges and the rows extended above and below the ridge to a uniform distance so that all rows will be parallel. The intervening terraces and adjacent areas can then be planted to close-growing crops in such ways that all of the irregular areas will be covered with a

protective cover. This makes it possible to eliminate all point rows. Where these are not objectionable and the row crops are planted over the terrace interval, rows on each side of the strip should be parallel to the terraces so that resultant point rows will be in the middle of the terrace interval.

The small tractors used now on many average-sized farms allow easier, quicker turning and make point rows much less objectionable. For this reason, a good many farmers having such tractors are laying their strips out with both sides on the contour and planting from both sides toward the center so that any point rows fall within the strip boundaries. This means that with both edges of the strips on the contour and the rows laid out parallel to these edges, the long rows are on the outside of the strips, a method that facilitates planting, cultivating, and harvesting with machinery.

Width of Strips. In terraced fields, the width of strips is usually adjusted to the terrace interval; but on unterraced land, the strips frequently should be narrower than the standard terrace interval. Here the width will be governed by the length and steepness of the slope and by the permeability of the soil, since all these factors influence the amount of runoff and erosion. As a general rule, the steeper the slope the narrower the strips of both cultivated and thick-growing crops.

Strips should seldom be wider than 100 feet to meet the requirements of soil conservation; but for practical farming, they can rarely be narrower than 50 feet. The width frequently can be adjusted advantageously to an even number of rows or to an even multiple of the width of the machinery that will be used in farming the strips. In determining the optimum width of strips, good judgment should be used to the extent of making slight adjustments, where possible, so that the width of the strips will fit the farming implements, particularly planters, drills, and harvesters.

Rotation Stripping. Crop rotations can be used as effectively on strips as on large fields. It is practicable to have approximately the same area of tilled crops, small grains, hay crops,

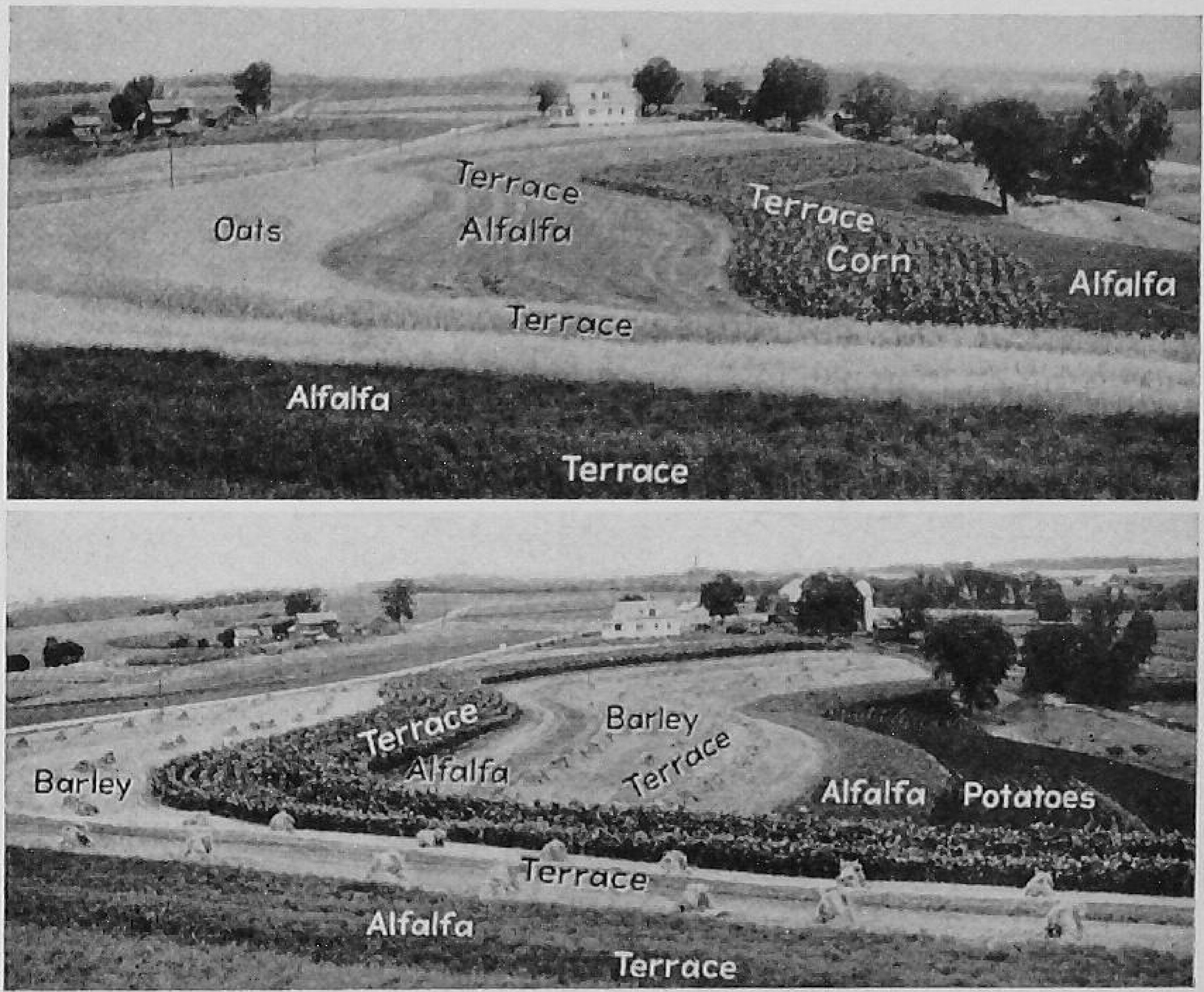


Fig. 49.—Upper: terraced field, farmed with 5-year rotation on contour strip-cropped basis—alfalfa, oats, alfalfa, corn, alfalfa—1936. Lower: same field in 1937, with preceding crops moved up slope. Upper barley strip in lower photograph follows oats because of failure of alfalfa seeding previous year. Note narrow strip of alfalfa was left below corn as buffer strip. Clinton silt loam, slope range about 6 to 12 per cent. Vernon County, Wisconsin. (Work by Soil Conservation Service.)

and grass under a strip-cropping system as under the regular field system. The only rearrangement is within the field (Fig. 49).

Maintenance of a good rotation is one of the principal features of the best type of strip-cropping system. The crop rota-

tion within the strips themselves and the arrangements (sequences) of crops as between strips are especially important. No two cultivated strips, as well as no two strips having the same planting or harvesting dates, should be adjacent. By rotating the strip plantings, the clean-tilled row crops usually can be made to follow crops like grass or legume that have a dense-fibrous root system, which tends to hold the soil and retard erosion until the roots are broken down by decay. In this way, the organic-matter content of the soil is increased or maintained, and its physical condition improved, so that the land absorbs water more readily and has increased capacity to resist erosion.

Permanent Stripping. For special purposes, such as taking care of critical slopes, in some parts of the country, it is occasionally advisable to establish either permanent or temporary strips that are not a part of the rotation. These are made use of generally in the form of *buffer strips* of perennial legumes, shrubs, grass, legume-grass mixtures, Sudan grass, grain sorghums, or, in some instances, small grain. The row crop or cultivated strips under this system may or may not be rotated. It is sometimes desirable to establish permanent strips in connection with either field stripping or contour stripping on irregular areas, in correction strips, or on critical slopes or other odd corners or portions of the field that are difficult to maintain in the regular rotation strip-cropping program. Frequently, these permanent strips can be devoted to the production of black locusts for fence posts or planted to kudzu or perennial lespedeza for forage or, under favorable conditions, to small uncultivated fruits—blackberries, plums, etc. Incidentally, most of these plants provide food and cover for wildlife.

A buffer strip is a more or less permanent contour strip, usually of variable width, planted to grass or other erosion-resistant vegetation that is not a part of the regular farm rota-

tion and that may or may not be harvested. The area planted to erosion-resistant crops under a buffer-strip system is much smaller than under a contour strip-cropping system; the buffer strips usually vary between 8 and 20 feet in width. Such buffer strips often are used on truck farms, where land is valuable and where erosion-resistant crops have no sale value and are not needed for farm use, or in orchards either in the tree rows or in the alternate spaces between rows. If the tree row itself is left in sod and cultivation across the slope is practiced, in time a benchlike terrace will be built up favorable to level cultivation.

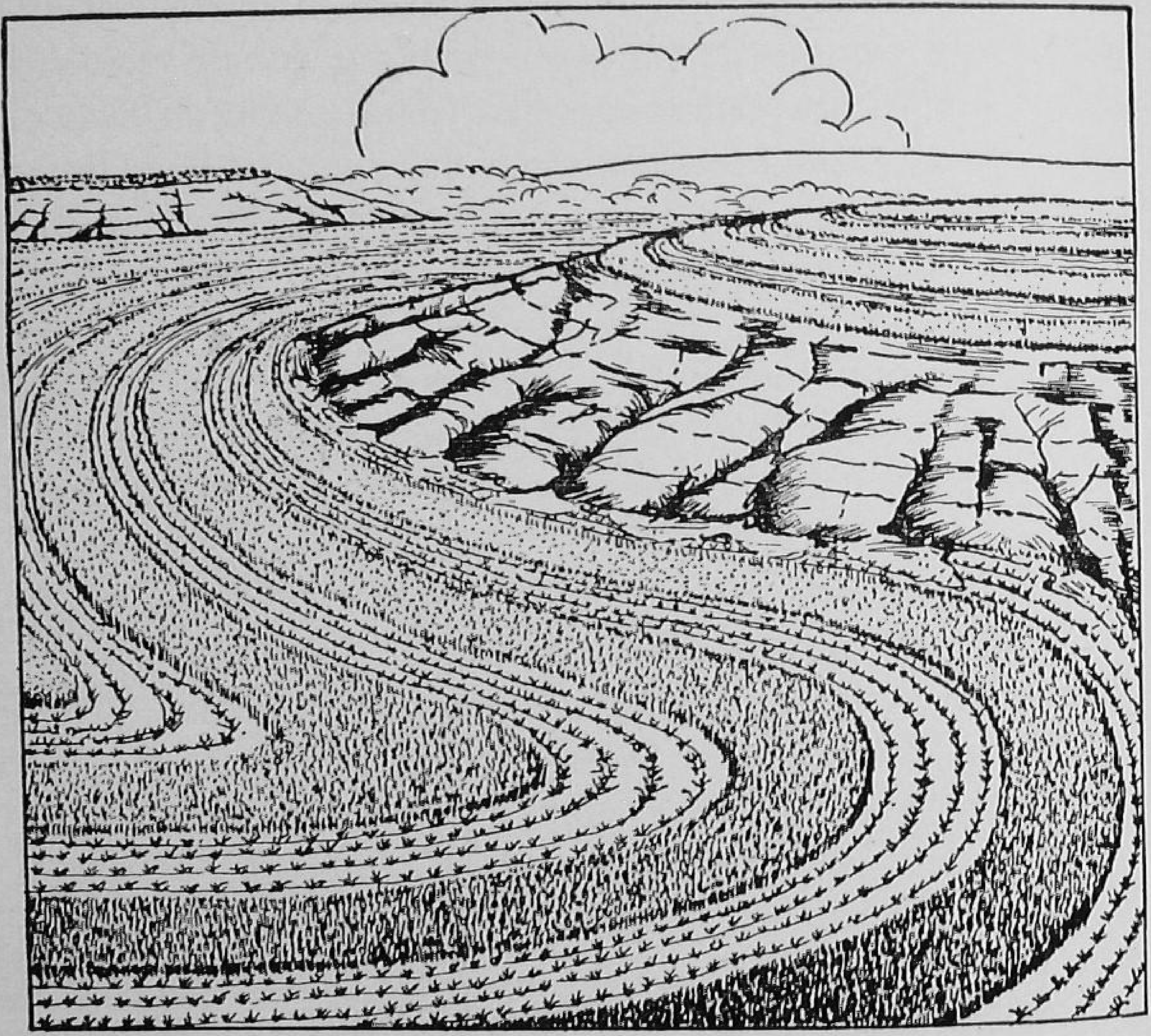
In rotated cultivated fields, a buffer system has little practical value. However, where erosion-resisting crops do not occupy a sufficient part of the field to allow strip cropping, buffer stripping together with full utilization of cover crops offers perhaps the next best method of vegetative erosion control.

The most effective use of buffer strips is on critical slopes and other especially vulnerable parts of cultivated fields that cannot be protected from erosion by ordinary strip-cropping or other common methods of conservation.

Where a field is broken by areas having slopes of 15 to 20 per cent or more, strip cropping, either alone or in combination with other soil-conserving practices, must be supplemented by the use of special types of "heavy-duty" perennial vegetation on these steep portions of the field. *Critical slopes* (Graph 1) may extend as fairly regular bands across the entire field, or they may extend only for a short distance along a surface irregularity. Where such slopes occur in cultivated fields, the vegetation generally grown on them should be a perennial forage crop rather than trees or woody vegetation. Such plantings of heavy-duty (stoutly resistant to erosion) perennial vegetation will provide year-round protection for those field inclusions

where, under cultivation, erosion is most critical; and when well established, they may be utilized for hay.

If, however, these slopes are continued under a system of row-crop farming, it becomes almost impossible to control erosion



Graph 1.—Critical slopes, where erosion progresses with excessive rapidity should be taken out of cultivation and seeded to grass or other permanent cover before the land is ruined.

on lower lying land anywhere in the field. Soil washed from such critical areas clogs terrace channels and contoured rows below, causing breaks and permitting the formation of gullies. Poor subsoil material, sand, and gravel derived from these areas often damage neighboring lower lands over which they are spread.

Unfortunately, adaptable perennial legumes are not available for all parts of the country. Over much of the Southeast, perennial lespedeza and kudzu give good results in the treatment of these critical areas. In the Northeast and in the Corn Belt, a combination of grass and legume mixtures, such as alfalfa with smooth brome grass, timothy, orchard grass, or bluegrass, makes good permanent cover for land of this nature. Grass or legume-grass mixtures may be used effectively in many parts of the West.

Where soil blowing is a common difficulty in fields used for vegetables, as on muck and loose sandy lands, special narrow strips are sometimes used with good success. Narrow hedges of privet, rye, corn, sorghum, etc., are used on sandy lands, and rows of willow trees and strips of small grain are used on muck areas.

Field Stripping. Field strip cropping is a modified form of contour strip cropping under which the strips are laid out parallel and across the general slope but not exactly on the contour. It is most commonly practiced on the wheatlands of the Great Plains. This system is frequently used on slopes with numerous surface irregularities that make accurate contour stripping impracticable. Where these field strips cross depressions, the rows depart from the contour to such an extent that water usually accumulates in erosive quantity in the low places. To avoid such dangerous accumulation, grassed waterways should be established and maintained in the depressions. If the strips deviate more than 2 per cent from the contour for distances greater than 100 feet, field stripping should give way to contour stripping. If surface irregularities are too great, as in hummocky or knolly glaciated country, planting solidly to grass, trees, or other adaptable dense cover is sometimes advisable.

Protective Cover Cropping. Protective cover crops are very important in safeguarding fields from erosion. They also serve

to absorb plant nutrients that otherwise might be lost by leaching and thus aid in their preservation for subsequent crop use.

The use of the term *cover crops* has become almost synonymous with *green-manure crops;* but from the standpoint of soil conservation, there is a significant difference. Crops may, and do, serve as cover crops that are not used as green-manure crops. Green-manure crops, however, are always of necessity cover crops.

If it were economically possible to grow only soil-protecting crops, other measures for preventing erosion would be less necessary. As it is, however, cultivated crops must be grown; so it is important where their use is feasible to make the widest possible use of cover crops (grasses and legumes), green-manure crops, grains for winter and spring cover, peas for summer as well as winter cover, and *catch crops* of various kinds in order to leave the soil exposed to erosion for a minimum period during the year. The purpose in growing a seasonal cover crop is, therefore, to protect and improve the soil when the regular cultivated crops are off the ground. (Some conservationists look upon any such seeded crop, as clover, peas, rye, and grass, that may provide protection from erosion as cover crops.)

Protection of the soil from erosion and the absorption of soluble nitrates that otherwise would be wasted are not the only roles played by cover crops. They also play an important part in soil economy by adding organic matter and, in the instance of leguminous cover crops, soil nitrogen. This is true in part, whether the cover crop is finally turned under or not. Most of the organic matter in soils is derived from the decay of roots.

Experiments at the New Jersey Agricultural Experiment Station have shown that when land, of the kind tested, is left in grass for 2 years, the amount of organic matter in the soil is actually increased by about 1,300 pounds per acre. Grass, com-

monly, is not only the best possible cover crop from the erosion standpoint but one of the best crops where a quick increase of soil organic matter is desired. Not only is organic matter a storehouse of nitrogen, but its mechanical effect on the soil is highly favorable. A soil rich in organic matter absorbs rainfall more readily than one with a deficiency of organic matter.

The choice of a cover crop will depend on local conditions, costs, use to be made of the crop, and other factors. These crops may be used for green-manuring purposes or merely for cover and to absorb nitrates or as catch crops to fill in between the harvesting of one principal crop and the planting of another. Such crops may be used for winter or for summer cover. In some instances, the protective effect can be extended by plowing only part of the field when preparing land for a subsequent crop. For example, crimson or bur clover preceding cotton may be plowed on the *balk system,* only enough furrows being plowed out at first to seed the cotton. Subsequently, the intervening strips can be plowed out as cultivation progresses. This not only extends the time during which the cover crop furnishes protection but allows for maturing the seed for reseeding the clover.

Various summer cover crops may be left on the ground through winter, thus providing, even though dead, a fairly good measure of soil protection. For example, crotalaria, soybeans, and cowpeas, grown to improve the soil, generally should not be plowed under in the fall unless a winter cover is to be seeded. If they are turned under in fall without a winter crop following, decay will result in the loss of much of the nitrogen and the bare soil will be exposed to erosion.

The seeding and use of cover crops should be handled as a part of the regular farm operations. Grass or legume-grass mixtures are seeded in the regular farm rotation in accordance with local requirements. *Temporary cover* or catch crops are seeded

as soon as possible after the main crop is harvested. For instance, a grain field in which no clover or grass-clover mixture has been seeded is plowed as soon as conditions permit, so that a catch crop, such as Sudan or soybeans, can be planted. On poor Northern soils buckwheat is commonly used.

In the Great Plains, cover crops for protection against wind erosion are best seeded on the contour if there is any significant slope, since contour cultivation aids in the conservation of rainfall for the protective crops. If the season is favorable for a good growth, the upper portion of such cover as Sudan grass or sorghum may be cut for fodder, leaving a stubble about 18 inches for protection purposes. When only a small growth is made, the entire stand should be left, since it is likely to be worth much more for soil protection than for forage. Where a field has been severely blown, it may be advisable to seed the entire area to a protective crop until moisture conditions permit better growth. In other instances, the protective crop may occupy strips of varying width, placed at suitable intervals.

Winter cover crops in the South are used both for soil protection and for soil improvement. They should be seeded early enough to establish growth before cold weather, but extremely early seeding is generally undesirable. The seeding date will depend on latitude. In Virginia, North Carolina, Kentucky, and Tennessee, seeding in corn is not commonly satisfactory. Farther south, velvet beans, soybeans, and the early-maturing strain of crotalaria are used extensively as summer legumes. Crab grass, Florida purslane, and beggar weed, all of which generally make a heavy growth after corn is laid by, also furnish satisfactory cover.

Blue lupine is well suited for sowing in peanuts just before harvest in the southeastern Coastal Plain region. It provides very good protection, especially where fertilized, even where

the fields are gleaned by hogs turned in after the peanuts are harvested.

Applicability of Cover Crops to Problem Areas. Winter cover crops are not extensively grown in the northern Appalachian and New England area. Hairy vetch is the only legume used to any considerable extent, although rye and other winter grains are planted by many farmers. A grass-clover mixture in a regular rotation gives excellent protection. Alfalfa and biennial sweetclover also afford good protection on suitable soils. For summer cover, crimson clover is used in the extreme north, whereas Sudan grass, millet, and buckwheat succeed in nearly every part of the region. On productive soils, rape, cowhorn turnip, and mustard may be used as catch crops, and soybeans may be used generally throughout the region.

Within the southern Appalachians, crimson clover, hairy vetch, Austrian winter peas, and bur clover are used successfully in South Carolina, Georgia, Alabama, southern Tennessee, and the less elevated parts of North Carolina. Elsewhere in the region, red clover, seeded alone or with a grass mixture, together with alfalfa and sweetclover on adaptable soils are among the more commonly grown crops that provide winter protection. Hairy vetch, seeded with rye or oats, or winter grains seeded alone can be grown as beneficial cover crops throughout the region. In the southern part, rye grass, either alone or with crimson clover, has proved very successful. For summer cover, soybeans and cowpeas with Sudan grass, millet, or sorghum are important wherever a temporary cover is needed. Annual lespedeza is perhaps the chief leguminous summer cover for the southern Appalachians.

The chief winter legumes now grown in the Atlantic and Gulf Coastal Plains region are Austrian winter peas, hairy vetch, crimson clover, blue lupine, and bur clover. Local experience should be the guide in choosing from this list.

In the rolling sections of the Southeastern states, especially in the Piedmont and upper portions of the Atlantic-Gulf Coastal Plain, it is generally a good plan to grow soil-holding, soil-building crops after or along with the soil-depleting crops. And this is not a bad idea to keep in mind for other regions, too. For the Southeast—on the more rolling lands—a good general rule with respect to cover crops is to have about two-thirds as much "grassland" in winter as in summer, using winter legumes, grains, and grasses.

In the Florida peninsula, winter legumes are not extensively planted. Here winter grains may be used generally, as may also rye grass and Natal grass, on the better soils. On the limestone soils of Alabama and Mississippi, biennial sweetclover, Hubam clover, and sour clover are grown successfully. Hubam clover and sour clover are promising for the area affected by cotton root rot in Texas.

For summer cover, a wide choice is available for the Atlantic Coastal Plain. Soybeans, cowpeas, annual lespedeza, velvet beans, and crotalaria may all be used, depending on soil and other conditions. Biennial sweetclover and alfalfa also make both winter and summer cover where soil conditions are suitable. For permanent cover, kudzu and Lespedeza sericea are recommended. An astonishingly good pasture legume for winter grazing is wild winter pea (Caley peas or Singleterry peas), especially on the limy lands of the Black Belt of Alabama and Mississippi. This legume is also promising on some of the sandy lands of the Atlantic-Gulf Coast region in Southeastern United States.

In the central prairie and eastern timbered border region, red clover, clover and grass mixed, alfalfa, and biennial sweetclover constitute the principal winter covers. Hairy vetch is grown to a limited extent in Michigan, usually with rye. Except in the extreme northwestern part of the region, winter grains make a

satisfactory cover. In parts of Oklahoma and Texas, Italian or domestic rye grass has given promising results for winter cover. For summer, soybeans can be used nearly anywhere in this region, and cowpeas and annual lespedeza southward from northern Missouri. In some localities, canning peas and Canada field peas are grown; but unless interseeded with clover, they do not afford protection in late summer because of their early harvest season. Clover and grass or clover alone and alfalfa or biennial sweetclover seeded in grain also furnish excellent summer cover throughout this region. Sudan grass and millet can be used also.

For the Ozark Highlands, small grains are regarded as the most reliable cover for soil protection in winter. Soybeans, cowpeas, lespedeza, sorghum, Sudan grass, and spring oats are effective at other seasons.

In the southern part of the Great Plains, winter grain is the most effective seasonal cover crop for winter. For summer, the sorghums and Sudan grass are most reliable. In the northern Plains, spring grain affords protection for spring and early summer, and the perennial grasses, especially crested wheat grass and western wheat grass, for winter. Sweetclover does well over parts of the area, particularly the eastern part where alfalfa also succeeds.

In the drier western areas, only irrigated crops can be relied on generally for seasonal cover. Aside from irrigated lands, chief reliance for winter cover must be placed on the native grasses, although winter grains can be used in some localities.

In the Pacific Southwest, special cover cropping is confined to the orchard areas. On nonirrigated land, winter grain, wild oats, bur clover, and alfilaria (an annual herb) provide fair to good cover. Cover cropping is a common practice in most of the citrus groves and deciduous orchards. Vetches, bur clover, sour clover, and mustard are effective for winter. Use is

made of domestic rye grass, alfilaria, fenugreek (a low annual legume), and small grain, especially wild oats. In the orchards of the Placerville section of California, permanent cover of domestic rye grass, redtop, or legumes is used, and sometimes Johnson grass. Satisfactory cover crops have not been found for the olive groves on dry land and vineyards on steep slopes. This is equally true of land annually planted to grain, hay, and beans.

Sesbania and other legumes are grown during summer in the Imperial Valley on land intensively cropped in winter, but their primary function is for soil improvement.

Cover crops are used regularly in the orchards of the Pacific Northwest. As a matter of fact, where orchards are cultivated during part of the growing season, they generally require special attention to the use of cover crop.

In the Willamette Valley of Oregon, vetch, alfalfa, red clover, alsike clover, and sweetclover cover thousands of acres every year.

Green Manuring. Green manuring is the practice of turning under green plant material to improve the soil. Although any thick crop will provide seasonal cover, special crops are grown for green manuring. Red clover, sweetclover, and alfalfa make excellent green-manuring crops when finally turned under, but they are rarely seeded for this particular purpose.

Crimson clover, hairy vetch, blue lupine, and Austrian winter peas are the most important plants used for green manuring in the South. Bur clover, sour clover, and Hubam clover also are used but on a much smaller acreage. Crotalaria and cowpeas are the chief summer legumes used for this purpose. Lespedeza is not often seeded for green manure, but the stubble of the grazed crop serves the same purpose in the South as red clover stubble does in the North. In the Corn Belt, sweetclover is

often seeded especially to be turned under for soil improvement. A native legume volunteering in wheat fields of western Iowa, known as *Wood's clover,* makes an excellent green-manure crop. Rye is used rather extensively, especially in the potato section of Delaware. It is turned under early and supplies some organic matter.

Green manuring in the Intermountain and Pacific Coast regions is confined to irrigated orchard or truck croplands. The crops most generally used are vetch, sour clover, bur clover, and mustard. Recently, a new system of mowing the cover crop and leaving it on the surface has been introduced in orchards and citrus groves of California. Italian rye grass is commonly used. It reseeds enough to maintain the stand. With repeated cuttings, a large amount of plant material accumulates on the surface. How successful this practice, which is a form of mulching, will be remains to be seen, but results so far have been encouraging.

In the Pacific Northwest, especially in Washington, where alfalfa is used as a permanent cover in irrigated orchards, the crop is mowed several times a year, and the material allowed to accumulate on the ground. This is disturbed only by the furrowing necessary for irrigation. In the Willamette Valley, vetch is frequently used as a regular green-manuring crop. In the Palouse, sweetclover seeded with peas is plowed under in June the following year in preparation for grain, thus serving the purpose of green manuring.

Groups of Plants Useful for Soil Conservation, Pastures, Etc. Plants that are useful for soil conservation may be classed conveniently into two groups: common farm and range plants and hitherto overlooked plants that offer promise for controlling erosion or contributing to better land use. Many of the former are introduced plants from Europe, Asia, and Africa; the latter group consists largely of native American species

whose utility was not recognized until the need for plants suitable for controlling erosion under various environmental conditions called attention to their value.

The more common farm and range plants, crops useful in erosion control, are those grown (1) in pastures and meadows, (2) as soil-building crops in rotations, and (3) as seasonal cover crops. These plants have a triple value: They provide a satisfactory soil-protecting cover and at the same time furnish hay or pasturage and serve as soil-building crops.

Pasture Grasses and Legumes. Permanent pasture consists mainly of those forage plants which make an effective cover for soil and water conservation. This is particularly true of sod-forming grasses where care is taken to establish and maintain a good ground cover. Where a good cover occupies the summit and a good sod the adjacent slopes, even steep lands are generally safe from serious erosion.

Since numerous plants can be used for pasture, adaptable species generally can be found wherever it is economically feasible to devote the land to permanent grass. Any classification of grasses as pasture or meadow plants is more or less arbitrary. When utilized for both purposes, they will be discussed here under the most common usage.

Bluegrass. Kentucky bluegrass is a good erosion control plant particularly adapted to the humid sections of the Northern, East North-Central, and East-Central states and many of the Rocky Mountain valleys. Canada bluegrass is somewhat less satisfactory for erosion control purposes as it tends to make a thinner stand. It will, however, grow on poorer, more droughty land.

Redtop and the Bent Grasses. These grasses are good sod formers and are useful on land too acid or poor for Kentucky bluegrass.

Smooth Brome Grass. Smooth brome grass, a good soil builder and protector, is particularly well suited to subhumid conditions (Fig. 50). Its dense sod forms an ideal protective cover for any slope on which it can be established, and the sod is highly resistant to trampling. It may be utilized for grazing

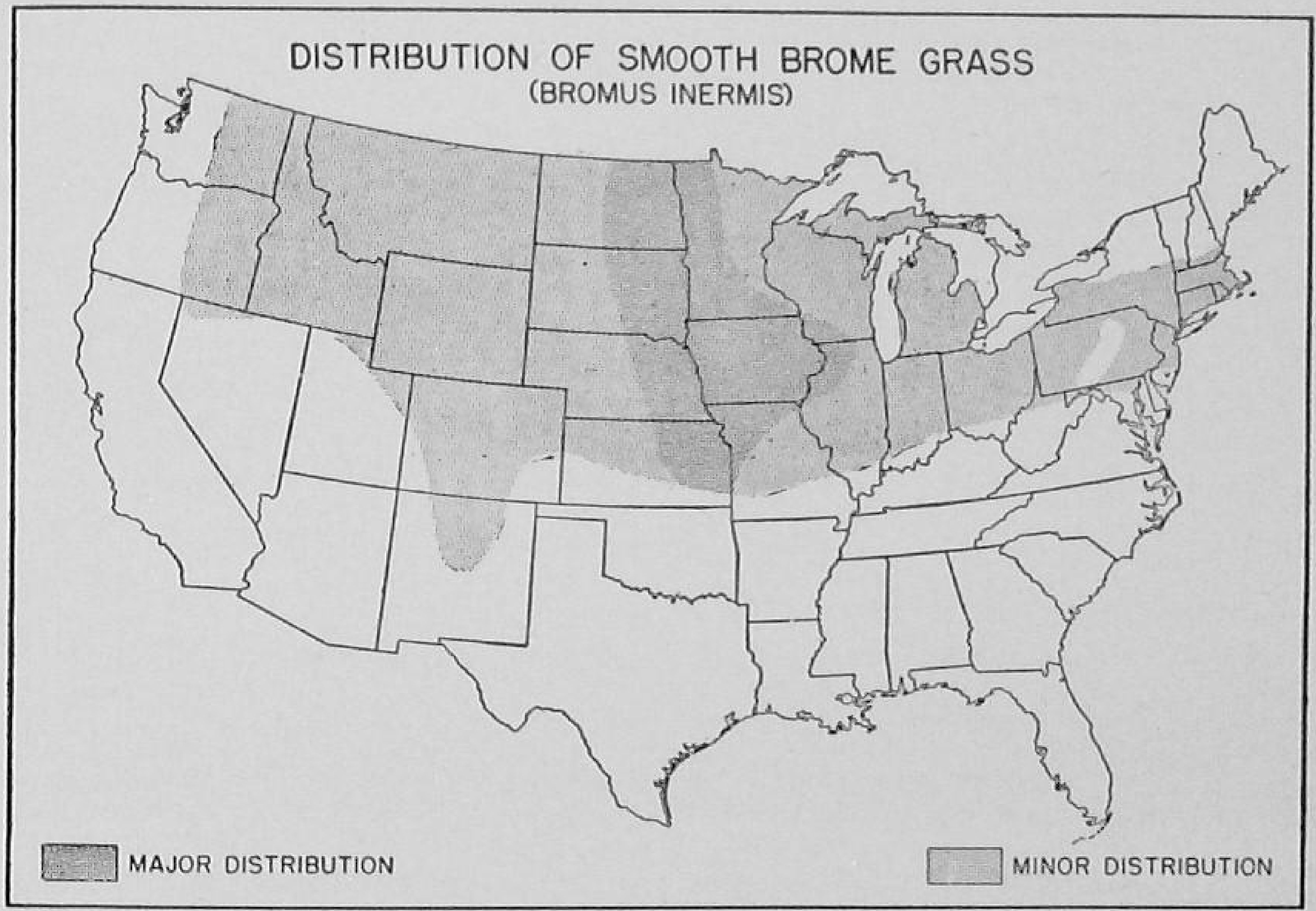


Fig. 50.—Distribution of smooth brome grass.

or cut for hay or seed. Smooth brome grown with a legume, such as alfalfa, makes excellent hay, and the stand remains reasonably productive for about five years (Fig. 51). The grass will need reseeding occasionally.

Bermuda Grass. This is one of the most common pasture grasses in the Southern states. In combination with lespedeza, it makes a good lasting pasture. It is especially effective as a protective lining for terrace outlets and diversion-ditch channels. It should be kept out of regular field rotations.

Dallis Grass. Although not ideally suited to erosion control because of its slowness in spreading, this grass is helpful, especially in gullies and waterways subject to gullying. Because of common inferiority of the seed, it is not easy to get dense stands. It generally should be used in such pasture mix-

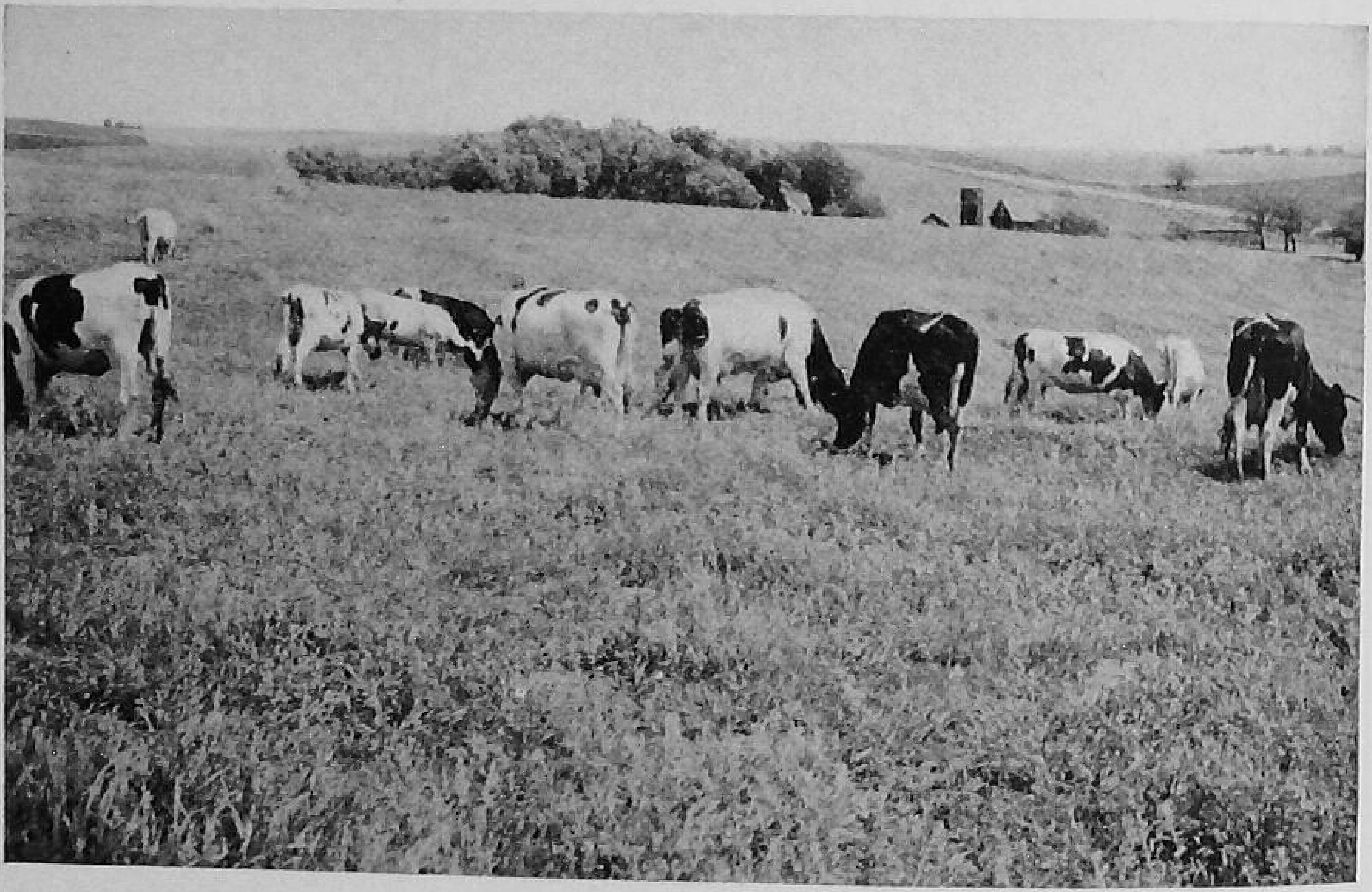


Fig. 51.—Contour-furrowed pasture planted to brome grass and alfalfa. Note windbreak around homestead. Nebraska.

tures as will insure a complete ground cover promptly. It does especially well on the calcareous lands of the Mississippi-Alabama Black Belt and is also useful on good lands elsewhere in the South (Fig. 52).

Blue Grama. Blue grama occurs in pure stands over most of the Great Plains (Fig. 53), producing good grazing and good seed crops almost every year. It is highly palatable and is one of the chief grazing plants on much of the western range. There appear to be distinct strains with the southern varieties

tending to be later in maturing and more vigorous than the northern strains.

Buffalo Grass. This is one of the most characteristic grasses of the semiarid Great Plains (Fig. 54). It produces a large

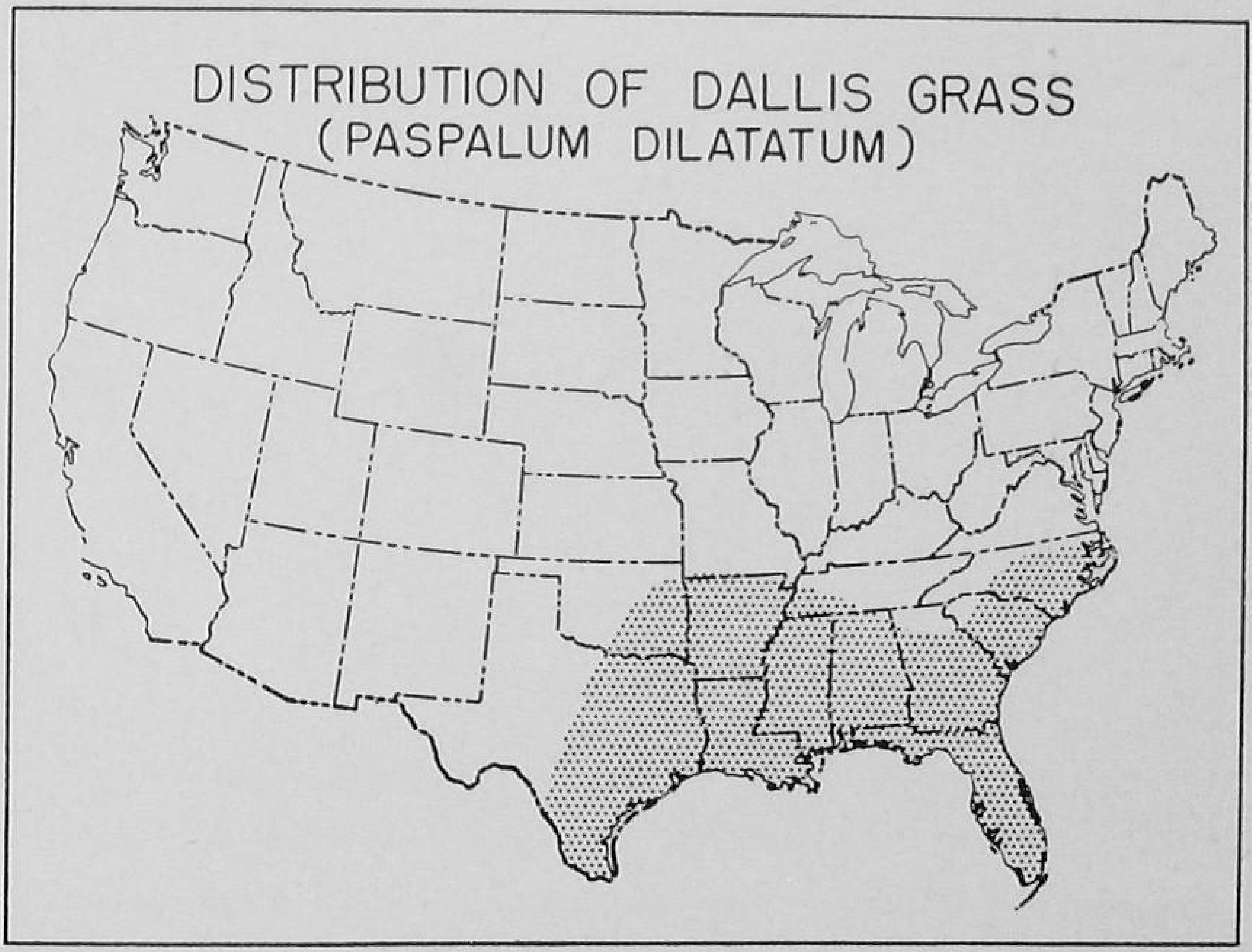


Fig. 52.—Distribution of Dallis grass.

amount of nutritious forage and forms a most effective erosion-resistant sod. Despite its excellent qualities for erosion control, the use of Buffalo grass has been somewhat limited by lack of seed. Recently, better methods for collecting seed have been developed.

White Clover. This plant, probably the most widely distributed of the true clovers, is used in most humid areas wherever soil conditions are favorable. Except for seed purposes,

it is seldom used alone but in mixtures with grasses. Ladino clover is a large form of white clover that produces more forage under favorable soil and moisture conditions. At present, it is produced principally in the Northeastern states and the irrigated valleys of Idaho, Washington, Oregon, and California.

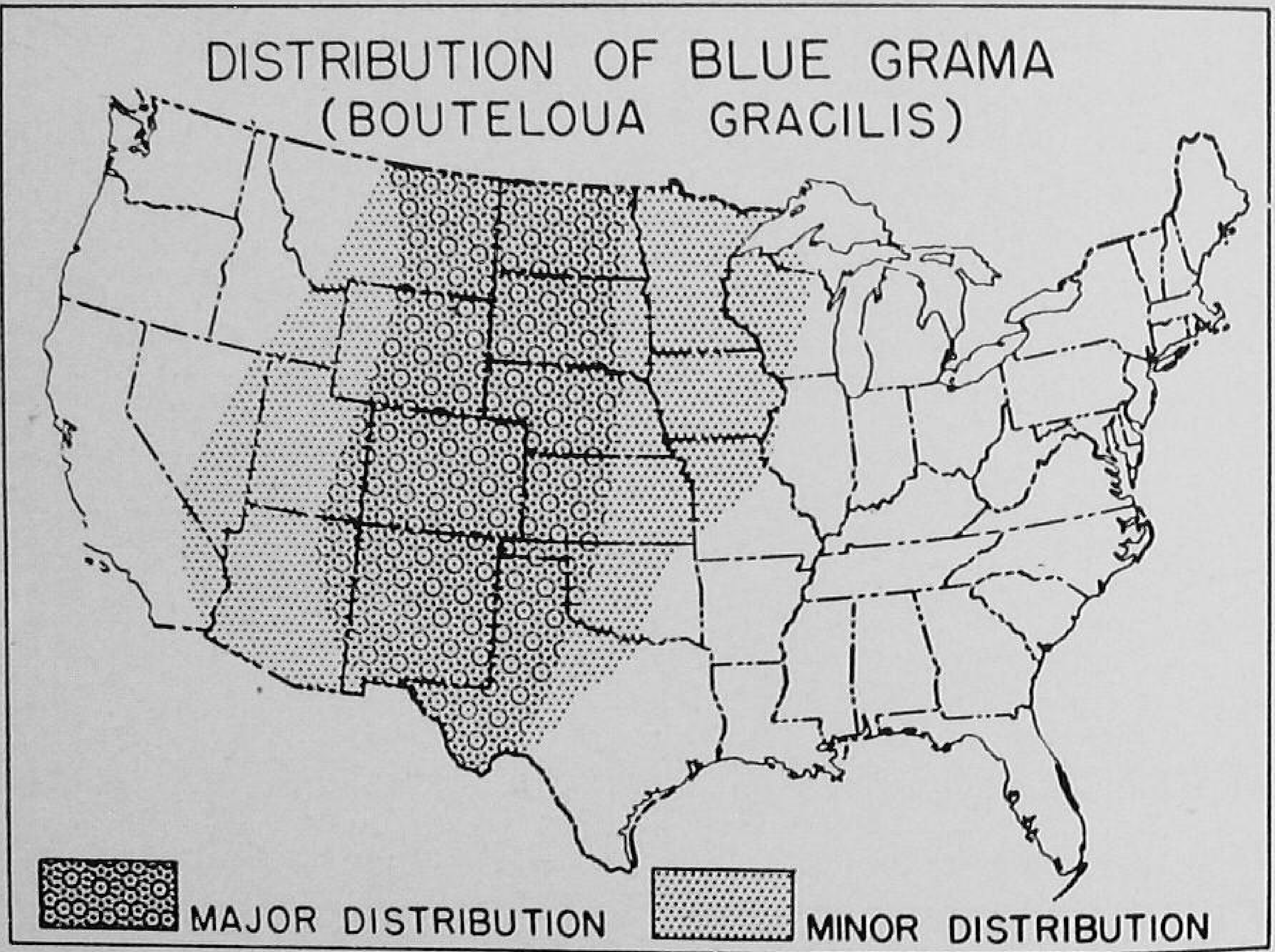


Fig. 53.—Distribution of blue grama.

The Hop Clovers. The two low-growing winter annual hop clovers are useful for late winter and early spring cover in the South. They are used chiefly in association with summer grasses. The species occur scatteringly throughout the humid parts of the United States, but they are of importance as cover and for grazing only in the South and Far West.

Sweetclover. Although sweetclover often is grown for hay, its main uses are for grazing and soil improvement. If lime is

available, this legume will grow almost anywhere that there is sufficient rainfall—around 16 to 20 inches or more.

Annual Lespedezas. Few plants except grasses are grown more in the south and central humid areas for conservation of soil than the annual lespedezas. Although not usually thought

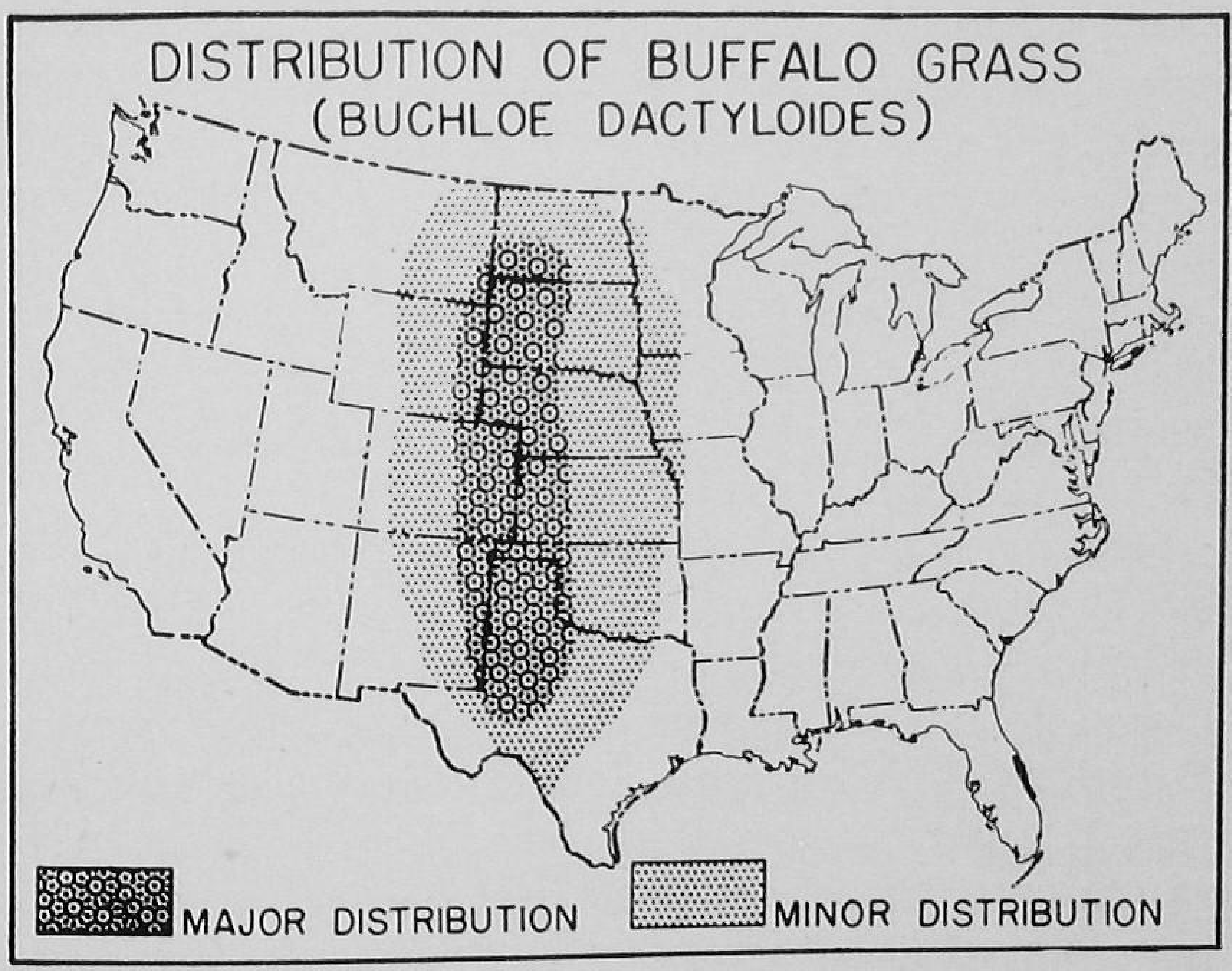


Fig. 54.—Distribution of buffalo grass.

of as continuing or permanent cover, they can be made to serve practically the same purpose over a term of years if allowed to volunteer. These plants make a dense, low cover of innumerable stems and leaves, which minimizes direct impact of rain on the soil and retards runoff. Annual lespedezas warrant extensive use.

Meadow Grasses. Meadow plants are often used as part of a rotation. In some instances, especially after alfalfa, a stand of some meadow grasses may be left for many years.

Timothy. Timothy is the most widely used grass in the Northeastern states. Its range extends as far south as the highlands of western North Carolina. It is also used in mountain meadows and on irrigated land in the Northwest.

Orchard Grass. When orchard grass is thickly seeded, it gives good erosion protection. It grows on somewhat poorer soils and will endure more shade than the better sod-forming grasses. Orchard grass has proved especially useful in the southeastern Piedmont and Ozark Highlands and is grown also in other sections.

Reed Canary Grass. Ordinarily Reed canary grass flourishes in the Northern states on seepage slopes and makes satisfactory long-term cover. It is used a good deal in freshly drained areas for hay and grazing.

Crested Wheat Grass. Introduced from Russia, this perennial bunch grass has been found particularly well adapted to the soils and rigorous climatic conditions of the northern Great Plains. Its marked resistance to drought, its deep, extensive root system, and its early spring growth and excellent reseeding capacity make it a most useful plant for erosion control over an enormous area in subhumid and semiarid regions. It is proving a very useful plant for rehabilitation of abandoned wheatlands of wind-erosion areas.

Sudan Grass. This standard forage grass can be grown nearly everywhere in the United States where the rainfall is adequate—something like 18 inches and above. In the humid East, it is frequently used as an emergency hay or pasture crop and also for temporary cover. Its most important place, however, is for checking wind erosion in the Great Plains. One of the most common treatments for eroded fields in the southern Plains is listing and the seeding of Sudan grass in rows, preferably on the contour.

Legumes for Meadows or Protective Cover. In some ways, legumes are preferable to grasses for conservation purposes, since they produce hay with a higher protein content and increase soil productivity by adding nitrogen. On the other hand, many of the most valuable legumes do not grow on badly worn soils, whereas some of the grasses thrive on all but the most sterile land.

Alfalfa. In adaptable areas, alfalfa is almost invariably the leading hay crop. However, it thrives only on land that is at least fairly productive and even then requires plenty of lime and phosphorus. Alfalfa is well suited for the development of long-term cover on sloping land, where the abundant growth effectively controls erosion and runoff. For most effective ground protection, alfalfa should be seeded with a grass, such as smooth brome or orchard grass.

Red Clover and Alsike Clover. Used in standard rotations, these crops make excellent cover. Commonly seeded on or with small grain, the first year's stand covers the ground after harvest of the grain during the following winter and for at least part of the next summer. Although these are northern plants, they can be grown in the upper part of the southern Piedmont with lime and phosphatic fertilizers. In parts of the South, however, they do not last through summer, nor will they grow under semiarid conditions. Alsike clover is a good substitute for red clover and has the added advantage of succeeding on poorer soils—particularly those less well supplied with lime and of somewhat poorer drainage.

Lespedeza Sericea. In the South, the principal legumes available for permanent or semipermanent cover are lespedeza and kudzu. Lespedeza sericea is a perennial well suited to a wide variety of soil conditions. It is also suitable for strip cropping, buffer strips, meadow strips, and marginal field and odd-corner plantings. Although it makes slow growth the first season,

subsequent progress is characteristically good, even under conditions of heavy weed infestation and poor soil. According to present experience, it appears to be adapted generally to the country south of the Ohio and Potomac rivers and as far west as eastern Kansas and Oklahoma. It has succeeded in some places north of the Ohio but is subject to winter killing where the temperatures go much below zero. This crop has an important economic place on the farm for the triple purpose of erosion control, hay production, and grazing.

Kudzu. Kudzu is a perennial vine of great value for soil and water conservation, hay, and pasture for all classes of livestock. It is being used in regular rotations with row crops, doing a splendid job of protecting the land from erosion, adding needed organic matter to the soil, and developing a more balanced land and farm program. It is also extensively used for heavy-duty work such as reclamation of gullies and stabilization of railroad and other cuts and fills.

Velvet Beans. These are strong-growing viny plants commonly planted with corn in the Cotton Belt. Planted with corn, velvet beans make an excellent late summer and early winter cover. They make good growth even on poor land and add liberally to the organic supply of the soil.

Some Overlooked Vegetation Useful for Erosion Control. Although for the present and immediate future, control of erosion by vegetation must depend largely on the use of those established crops for which a seed supply is available, it is recognized that many native species as well as some newly introduced hold promise for wide areas and for special purposes or local use.

As the work at Soil Conservation Service nurseries has progressed, many species and strains that heretofore had received very little consideration have been found to have exceptional value for various erosion control and land-use practices. Over-

looked until this particular need developed, many such plants because of especially desirable characteristics are now being brought into the conservation-farming program.

Gramas. In addition to blue grama previously mentioned, other gramas include some of the most valuable grasses of the Great Plains and various parts of the West. They stand high in the scale both for forage and for erosion control. The species so far tested are all perennials. *Black grama* is distributed more or less generally through southern New Mexico, Arizona, and western Texas. *Hairy grama* occurs in scattered stands throughout most of the Central and Rocky Mountain states but reaches its maximum usefulness as a range plant in Arizona and New Mexico. *Rothrock grama* is limited to the southern half of Arizona and southwestern New Mexico, where it occurs extensively in pure stands.

Wheat Grasses. The native wheat grasses are of great importance. *Western wheat grass,* a perennial that spreads by creeping rootstocks, is an important hay grass. It produces a quick ground cover and a heavy sod. Its tenacious soil-binding habit makes it especially useful for sodding terrace outlets and channels, stabilizing gullies, and protecting stream and reservoir banks against wave action. It is useful in the reclamation of abandoned farm lands and some types of depleted range. It is quite generally distributed through the West and has been introduced in localities east of the Plains. *Blue-bunch wheat grass* and *beardless blue-bunch wheat grass* are much alike, but the latter, being awnless, makes a more desirable grazing plant. The former occurs from Alaska to California and eastward into New Mexico, Colorado, Wyoming, and Montana, whereas beardless blue-bunch wheat grass is found chiefly in the intermountain region and the Pacific Northwest. Another stolon-forming species is *thick-spike wheat grass,* frequently found on

drifting, sandy soil. It is a sod-forming grass that makes a more nearly complete cover.

Bluestems. The big and little bluestems once covered wide areas in the prairies, particularly from Illinois to Oklahoma. *Big bluestem* is a tall, leafy plant of bunch habit but with a deep and extensive root system that furnishes good soil protection. It occurs in the eastern parts of Oklahoma, Kansas, Nebraska, and South Dakota. *Little bluestem* is also a bunch grass of wide distribution. It occurs in dense stands where the soil is good and moisture plentiful. Its leafiness and vigorous root system make it a very good plant for control of erosion. *Sand bluestem,* widely distributed throughout the Great Plains, is especially suited to sandy soils. Matured hay of sand bluestem spread over eroded land serves as a protective cover until the seedings become established. *Broom sedge,* a bunch grass that resembles little bluestem, is widely distributed on abandoned land from Pennsylvania to the Gulf. Establishing itself readily in dense stands, it has served a highly useful purpose in conservation of soil, especially on temporarily idle and abandoned land. It might well be encouraged until better grasses can be substituted.

Reed Grasses. Two of the reed grasses—*giant reed grass* and *long-leaved reed grass*—of wide distribution on light sandy soil through the Great Plains have been found useful in erosion control practices. An effective method of establishing these grasses on sand dunes has been by scattering the full-ripe hay over the surface. This temporarily stills the sand and furnishes protection until the young plants are established.

Blowout Grass. Another grass useful in controlling "sand blows" is *blowout grass,* which grows naturally on the deep, loose sands of the Great Plains, particularly the dunes of the Texas Panhandle section and the Nebraska sand hills.

Beach Grasses. The grass most widely used in the control of dunes along the seacoast and shores of the Great Lakes is *beach grass.* The European species, Holland grass (*Ammophila arenaria*), has become established along the Pacific Coast north of San Francisco, whereas the similar American species (*Ammophila sp.*) is native to the Atlantic Coast and the region around the Great Lakes. Both species are large, coarse, perennial grasses that grow rapidly from creeping rootstocks. They have been used extensively on both the Pacific and the Atlantic seaboards for stilling coastal dunes while other permanent vegetation is being established. Since the plants produce little or no seed, increase must be by vegetative propagation.

Wild Rye Grasses. Several species of wild rye grasses occur from the Great Lakes to the Pacific Coast. They have a definite place in the conservation program because of their ability to establish quick ground cover. *Canada wild rye* and *blue wild rye* are coarse, vigorously growing perennials that produce an abundance of seed. Both grow rapidly and form good ground cover. Blue wild rye is of greatest importance in the Pacific Northwest, where it is useful for grazing as well as for erosion control. *Beardless wild rye* is a sod-forming grass well suited to the Pacific Northwest. *Elymus mollis* is being used effectively to supplement beach grass in the stabilization of sand dunes on the Pacific Coast. A species of lime grass recently introduced from South Africa appears to offer possibilities in the control of wind erosion because of its underground stoloniferous habit, coarse tough foliage, drought resistance, and adaptation to sandy soils.

Bluegrasses. Two of our native species of *Poa* deserve special attention: Nevada bluegrass (*P. nevadensis,* Fig. 55) and Sandberg bluegrass (*P. secunda*). Both are tufted perennial bunch grasses, extremely drought resistant and highly valuable for

forage and erosion control. Since reproduction is by seed, range-management practices should be such that natural seeding can take place. Superior strains of Nevada bluegrass have been found through selection. Sandberg bluegrass comes up and persists on semidesert and rocky land where other native

Fig. 55.—Nevada bluegrass, four selections taken from the native vegetation in the Pacific Northwest and growing in the cooperative Soil Conservation Service–Washington State College nursery at Pullman, Wash.

grasses have disappeared. It withstands both trampling and vegetative competition. Because of early seed production, the plant is particularly useful for erosion control. Seeding trials, however, indicate difficulty in establishment from seed.

Rough-stalked meadow grass (*Poa trivialis*) is less resistant to heat and drought than Kentucky bluegrass, which it resembles. It is especially suited to moist, shady places and appears to be a good grass in northerly areas for seeding in diversion ditches and runoff-disposal channels where moisture is constantly present.

Curly mesquite has a tufted, stoloniferous growth habit and is highly resistant to drought and heavy grazing. *Galleta grass* has scaly rootstocks and a deep, tenacious root system that makes it important as a soil binder. It is also resistant to heavy grazing, recovering rapidly under protection.

Switch grass is a widely distributed perennial that reaches its greatest usefulness in the Great Plains. It develops extensive rootstocks and a leafy foliage, which, if cut at the right time, makes fair hay. If left on the ground during winter, the dead material offers protection against the wind and forms a natural barrier to snow and soil drifting.

Blue panicum, a native of the Southern Hemisphere, appears to be quite at home in the Southwest. It is drought-resistant, has spreading rootstocks, makes a large, rapid growth, and produces heavy crops of seed that are suitable for birds. It promises to become useful for several conservation purposes, including planting for windbreaks.

Sand dropseed, an important native plant of the Great Plains, is commonly found on sandy soils. It is among the first grasses to appear naturally on unused farm land. Although not highly palatable, it provides effective ground cover. Seed harvested from native stands with strippers is often clean enough to be planted directly with farm equipment. A seeding rate of 2 pounds per acre has given a satisfactory cover. Scarification of the seed is necessary for best germination.

The Needle Grasses (*Stipa spp.*). They occur generally throughout the Western states, particularly on dry, sandy plains and foothills, where they begin growth early and remain green over a long period. The needle grasses find their greatest use for conservation purposes by virtue of their persistent pioneering qualities, resistance to grazing, deep fibrous root system, drought resistance, and ability to produce good cover under severe extremes of both soil and climate.

The Fine-leaved Fescues. In Northeastern United States, these fine-leaved fescues will grow under conditions of poor soil, drought, and shade that are too severe for bluegrass. Their use is recommended on slopes of this character or for seeding ski trails and other places where summer erosion may start serious gullying.

Kikuyu Grass. This South African grass spreads by runners that root at the nodes. It has been used to a limited extent in southern California in gully-control work and has proved valuable as a protective cover for small dams. Where adaptable, it is a vigorous grower and an excellent grazing grass. It will not endure frost.

Other South African grasses that may have value are weeping love grass (*Eragrostis curvula*) and Lehmann love grass (*E. lehmanniana*). The first is a large bunch grass; the latter, a semi-creeper. Both produce an abundance of cover and heavy crops of seed. Although apparently adapted to the southern half of the United States, they may also have, because of ease of seeding and rapidity of development, an important place as annuals in control of erosion farther north.

Harding Grass. This grass, introduced from Australia where it is more commonly known as *Toowoomba grass,* promises to become a useful plant for controlling erosion in the warmer parts of the Southwest and along the Pacific Coast. It forms large, dense clumps with an extensive root system and produces an abundance of leafy foliage that remains green and suitable for grazing during the most of the winter. It is quite resistant to drought. The large plump seeds are much relished by birds.

Questions

1. What is the place of vegetation in soil and water conservation?
2. How are vegetative practices related to engineering control practices?

3. What is the place of crop rotations in practical conservation farming?

4. What effect do crop rotations have on yields? On soil health?

5. Give an example of a rotation especially useful for erosion control.

6. What is strip cropping?

7. How does rotation stripping differ from (*a*) permanent stripping, (*b*) field stripping?

8. Explain protective cover cropping.

9. How long should an erodible field be covered with a protective crop?

10. Give example of a good regional cover-cropping practice.

11. What are the objectives of green manuring?

12. Why do growers of cigarette tobacco object to legumes in tobacco rotation?

13. Name four important American pasture grasses. Three important pasture legumes.

14. Describe crested wheat grass, Lespedeza sericea, kudzu, velvet beans. Give their principal habitats and use.

15. Name five native grasses that were overlooked as farm-land plants until recently. Give their principal qualities and habitats.

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CHAPTER 11

Contouring

PRESENTING:

The Purpose of Contouring
Field Contouring
Garden Contouring
Pasture Contouring
Range Contouring
Contouring for Flood Control

Contouring refers to any tillage practice or mechanical treatment of cultivated, pasture, range, or other class of land applied across the slope on the level, that is, on the contour. Over most of the United States, it has been customary to apply the various tillage practices in straight lines approximately parallel to field boundaries, regardless of the direction of slope. In contrast, contour cultivation disregards field boundaries and straight lines completely, by following curved lines whenever necessary to stay on the level.

The Purpose of Contouring. In regions of low rainfall, the primary purpose of contour farming is to provide the greatest possible conservation of rainfall; in humid regions, on the other hand, the primary purpose is to reduce soil loss by water erosion. The objectives in both instances are attained in practically the same way. The furrows between the ridges developed by contour-tillage operations catch and hold the water, or part of it, and store it in the soil, thus reducing runoff and erosion and bringing about a more uniform distribution of moisture.

Contour farming has other advantages. Among the most important is the saving in power, time, and wear on machinery. It has been practiced in various parts of the world for hundreds of years. In the United States, contour cultivation was practiced in some localities more than a century ago. It has been extensively employed in the Southeastern states, where the use of hillside ditching and terracing probably encouraged its development. Outside this area, the practice still is not used nearly enough.

Since the establishment of the Soil Conservation Service, with its many demonstrational areas, and later through technical assistance provided to soil conservation districts throughout the country, thousands of farmers have come to recognize contouring as a necessary part of effective erosion control on cultivated land. Ranchers also are finding it a very important tool in conserving rainfall for the replenishment of grass on overused ranges.

Field Contouring. Contouring is a necessary adjunct to strip cropping of fields and should be used in connection with terracing as a means of providing additional protection for the interterrace area. On some areas of gentle slope, contouring alone sometimes provides adequate control of erosion.

The practice is employed extensively as a means of conserving water in dry-land areas, especially those affected by wind erosion. Here, tillage operations generally are performed with some type of furrowing implement, principally the lister. The damming, or basin, lister, which develops a dam at intervals in the lister furrow, is coming into quite general use in some localities where the land is nearly level.

Even contour furrows produced by wheat drills, with their little water-holding capacity, often retard the rate of runoff and so conserve some water. From the standpoint of water conservation, wheatland in the Great Plains generally is benefited by

level terraces, even where the land has a slope of less than 1 per cent. Contour listing, both with and without basin attachments, is being used more and more in areas affected by wind erosion. This is especially true in the southern Plains.

Contouring and terracing go well together. Contour tillage without terracing is an effective means of checking runoff and controlling erosion only on relatively gentle slopes and under conditions of gentle rainfall. Where there is considerable runoff, the contoured rows should be buttressed by terraces. Contouring, on the other hand, is one of the least expensive and most effective methods for maintaining terraces in good working condition.

The location of contour rows is made by staking out guide lines on the exact contour at intervals of about 100 feet up and down the slope. Steep and irregular slopes require close spacings for the guide lines, and the flatter or smoother slopes, longer spacings. The rows are run parallel to the guide lines for varying intervals up and down slope, depending on the regularity (smoothness) of the surface. It will frequently be necessary to take care of irregular surface features by introducing some short rows or irregular strips to be used for grass, legumes, etc., in a system of strip cropping.

Garden Contouring. Cultivation on the level is important in gardens on sloping land to prevent erosion and to conserve rainfall. In very small gardens, of not more than about 100 feet width and not steeper than about 5 per cent where the topsoil is shallow over impermeable clay or about 10 per cent on sandy loam, pretty good contouring can be done by the eye, especially where a little practical testing is done. Such testing can be done by scraping up a small ridge of soil across the slope along the upper side of the garden located as nearly on the contour as it can be placed and then checked by watching the behavior of water during the next rain or when a few buckets

of water are poured into the depression above the ridge. Corrections can be easily made by slight changes in the location of the furrow as indicated by the flow or ponding of the water. A slight gradient toward one side of the field would not be very serious, especially on impermeable clay soil. As a matter of fact it may be desirable.

It is easier and better to locate the exact level line or a gently sloping line, if desired, by the use of a level. If a hand level cannot be procured, satisfactory results can be obtained with a cheap carpenter's level fastened on a stick or in a frame provided with simple sights attached to the ends of the level.

If the garden is not larger than about 100 by 100 feet, it frequently will be possible to establish all the furrows after locating the first one along the upper side of the plot by running the others parallel to the first.

Pasture Contouring. Contour furrowing of pasture land is a practice that was used only to a very limited extent, if at all, before the recent advent of the nation-wide soil conservation program. During the early days of the program of the Soil Conservation Service, terraces were used in pastures for moisture conservation as well as for control of erosion. It was found that on slopes ranging generally from about 5 to 25 per cent or more, regular terraces did not provide satisfactory distribution of water. And so the terraces were made constantly smaller and brought closer together, until finally they became no more than contour furrows or a combination of furrows and ridges.

Range Contouring. The contouring of range lands has proved a very beneficial practice (Fig. 56). In general, however, contour furrowing should be resorted to only where good grazing practices fail to give a satisfactory cover of vegetation, and the practice should be applied only where the soil is deep and absorptive. Furrows are least effective on shallow and

highly permeable sandy soils. Observations indicate that on heavy land with deep topsoil, furrows about 5 inches deep, spaced at intervals of 42 to 84 inches, give good results.

Although various types of implements have been used to construct contour furrows, the three-row lister, with the middle

Fig. 56.—Eighty per cent increase in grass (buffalo grass and grama) following contour furrowing of this 240-acre tract in the Colorado Plains, at a cost of 46 cents per acre. This increased growth was due to conservation of rainfall that heretofore had run off the land as waste water.

bottom removed, has proved one of the most practical. It is highly desirable that a strip of undisturbed sod be left between the furrow slices. Accordingly, listers with the moldboards removed and even with the shares clipped, as a means of reducing the area of grass to be covered, have given especially good results. This procedure should be followed, generally, where a two-row lister is used. A chisel fastened ahead of the lister point has proved helpful in the furrowing of land having impervious, compact subsoil. Moldboard and disk plows, graders,

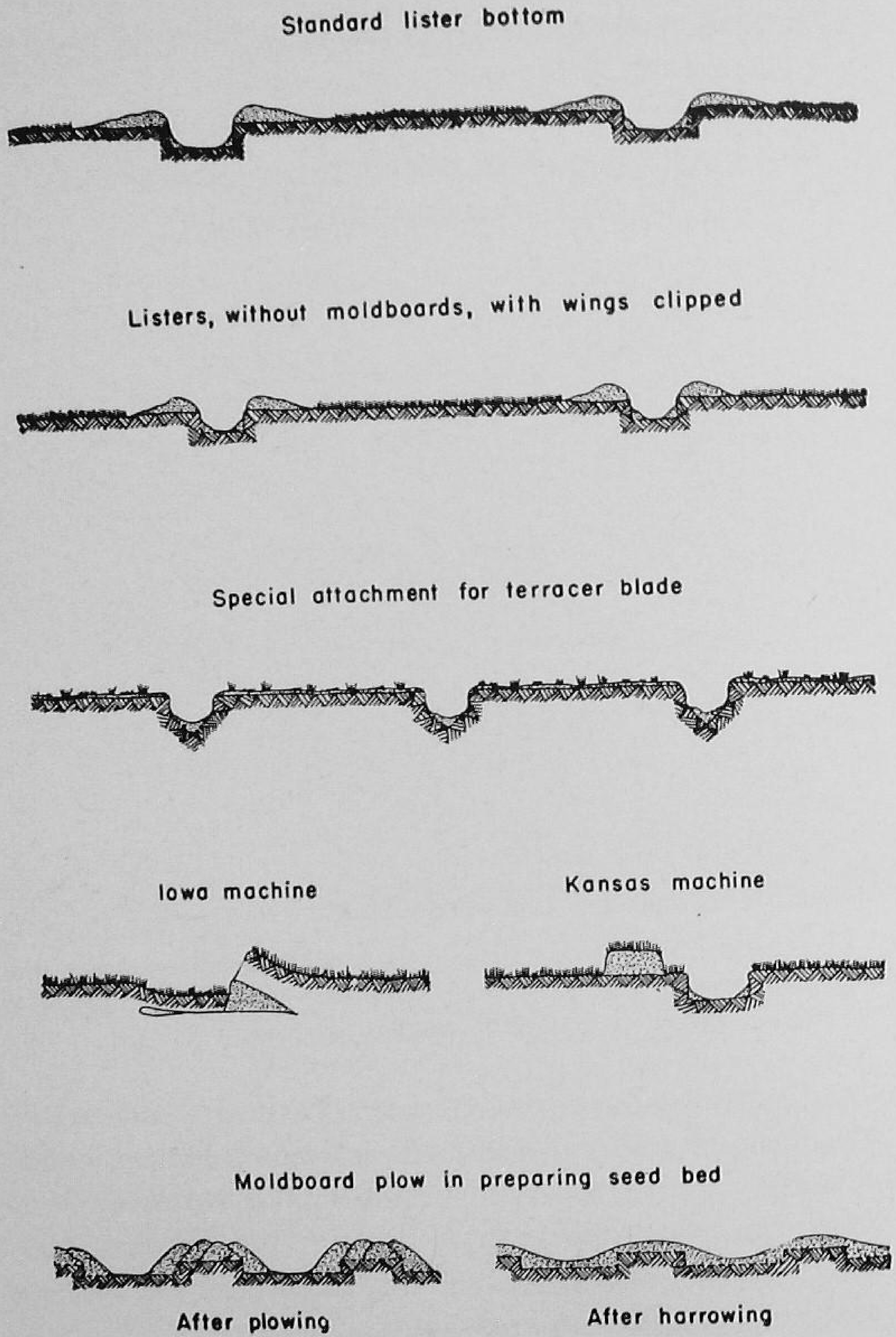
and various special-type implements (Fig. 57) also have been used in many parts of the country.

The use of the eccentric disk is one of the newer developments that has great promise for effective and economical contour furrowing on certain kinds of range land.

Fig. 57.—Contour furrows in Colorado made with terracer equipped with furrowing attachment. The purpose is to conserve rainfall that runs off as so much waste. (Work by Soil Conservation Service.)

Contour furrows have proved more practical than contour ridges in those low-rainfall areas where smooth surface conditions prevail. The furrow has a number of advantages: It revegetates much more quickly than the ridge and does not interfere with mowing operations. Cross sections of the various types of furrows are shown in Graph 2.

It is useless to attempt range restoration by contour furrowing or other mechanical means as long as overgrazing and other injurious range practices are continued.



Graph 2.—Cross section of various types of furrows.

Contouring for Flood Control. Since contour furrows store rainwater at or near the point where it falls, they obviously have a definite value for flood control. In the operations of the Soil Conservation Service, floods apparently have been effectively controlled on a number of small watersheds where all or most of the area was contour furrowed. Table 7 shows the size of furrows and the spacing necessary to store various quantities of rainfall within watersheds susceptible to treatment.

TABLE 7. SPACING AND SIZE OF CONTOUR FURROWS REQUIRED TO STORE VARIOUS AMOUNTS OF RAINFALL

Storage capacity, in. of water	Cross section, sq. ft., and spacing, ft.					
	Sq. ft.	Ft. apart	Sq. ft.	Ft. apart	Sq. ft.	Ft. apart
0.50	0.5	12.0	1	24.0	2	48.0
1.00	0.5	6.0	1	12.0	2	24.0
2.00	0.5	3.0	1	6.0	2	12.0
3.00	0.5	2.0	1	4.0	2	8.0
4.00	0.5	1.5	1	3.0	2	6.0
5.00	0.5	1.2	1	2.4	2	4.8

Questions

1. What is contouring?
2. Name some of its practical uses.
3. How are surface irregularities taken care of in field contouring?
4. What are the most important essentials in range contouring?
5. How does field contouring differ from garden contouring?
6. How are contour lines located?

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CHAPTER 12

Terracing

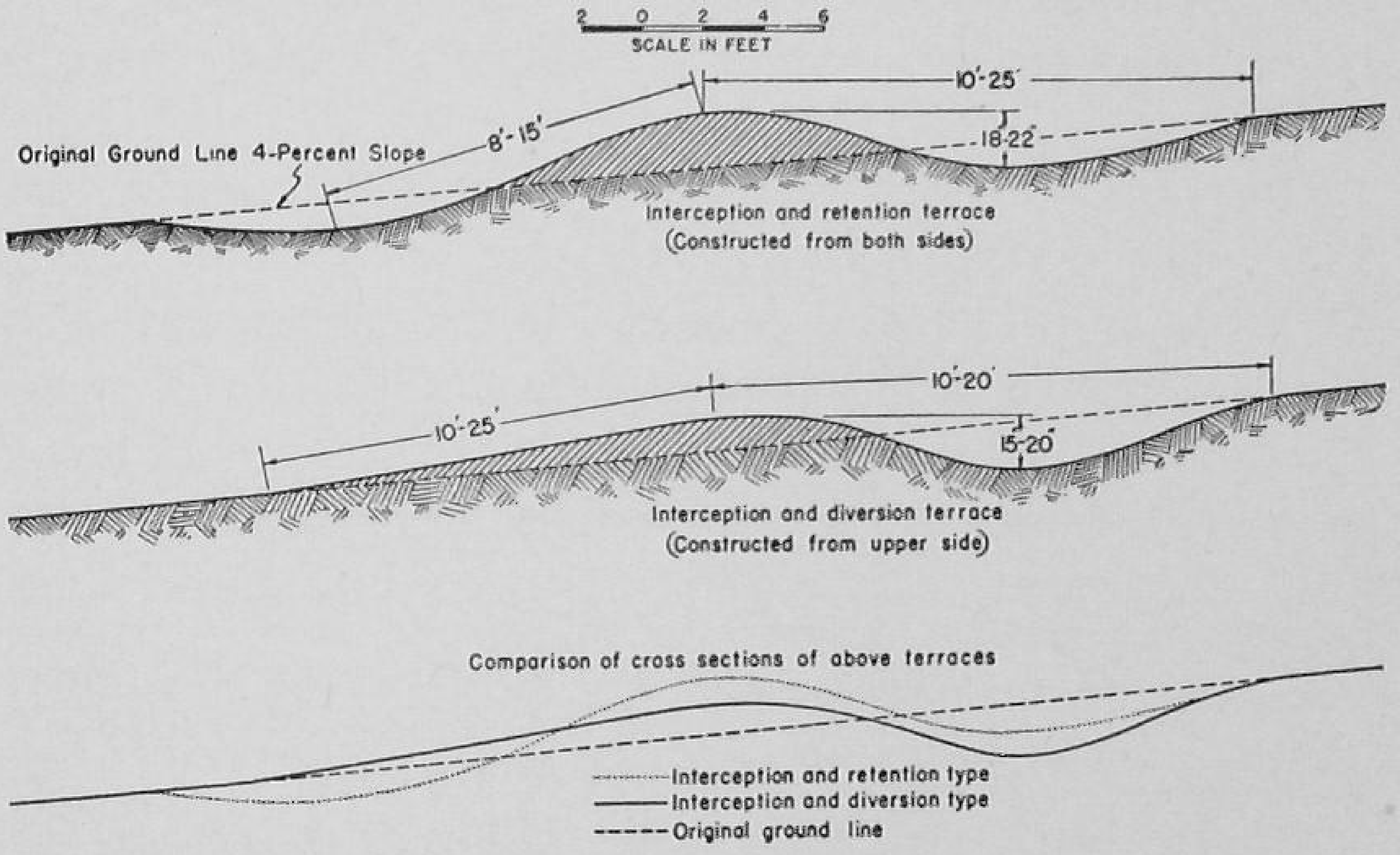
PRESENTING:

Features of Modern Field Terraces
Types of Terraces
Basic Principles in Terracing
Planning Terracing Work
Level Terraces
Cultivation of the Terrace

The field terrace, as used in the United States today, is essentially an artificial measure—an earthen embankment adjusted to soil and slope—designed primarily for control of runoff in high-rainfall areas and for conservation of water in low-rainfall areas. Control of erosion is the ultimate objective in the more humid areas and, together with conservation of water, the most important objective in dry regions.

Features of Modern Field Terraces. The basic mechanical feature of the ordinary field terrace (sometimes called *diversion ditch*) is a channel, with a ridge below, constructed across the slope at suitable intervals and grade to intercept and divert runoff before it gains sufficient volume and velocity to cause excessive erosion of the soil. In the construction of the modern field terrace, spacing, size, and slope are so regulated that runoff can be collected and conveyed across the field slowly along the channel to a protected outlet. Usually, both channel and ridge have a broad cross section, so designed as to permit cultivation over the entire structure. Level terraces are constructed

somewhat along the same mechanical lines as the graded structure. Their chief function is to retain and distribute rainfall that otherwise would be lost as runoff. Outlets are not provided for level terraces when the purpose is to hold all the rainfall.



Graph 3.—Comparative terrace cross sections after settlement and cultivation.

Types of Terraces. Classified roughly, the three principal types of terraces are as follows:

1. Bench terrace, designed to (*a*) control erosion by reducing the slope of the cultivated area and (*b*) make steep land available for cultivation.

2. Graded terrace, designed to intercept and divert runoff at nonerosive velocities.

3. Level terrace, designed to impound rainfall so as to store it in the soil for crop use (see Graph 3).

Bench Terrace. In various parts of the world, bench terraces have been extensively constructed at great expenditure of labor in order to make cultivable or to stabilize sloping land. Such

structures consist of nearly level benches that cross slopes in a series of steplike earthen platforms. The platforms are separated by steep to almost vertical *risers* or retaining walls supported by rock or vegetation.

Their use has been restricted largely to areas of dense population where the supply of level and moderately sloping land is insufficient for the needs of the people and where labor is cheap.

The practice of bench terracing is almost as old as agriculture itself. Centuries before the Conquistadors ascended the Andes, the pre-Incas had attained great skill in the construction of essentially level terraces, supported by artificial walls of stone. The structures were used extensively in the building of broad fields in the valleys and in the establishment of narrow contour fields on steep mountain slopes. Many of these artificial terraces are still in use.

In Mexico, somewhat similar bench terraces were constructed in various localities, as in the vicinity of Tenancingo.

A disturbing consideration is that although these lands are still in use where the walls have held up, the structures generally are not being repaired in these old regions and new ones are not being built except in a few new localities, as in Puerto Rico and California.

The *California type of bench terrace,* which recently has come into extensive use in the citrus groves of that state, usually is constructed in the following manner: Rows for planting trees are laid out on irrigation grade lines, varying with the soil and the slope of the land, and along these lines a small ridge is thrown up with two or more furrows. On this ridge, the fruit trees are planted. Irrigation water is applied along the upper side of the ridge. Subsequent cultivation is in the direction of irrigation and is conducted in such a way that a narrow

strip of vegetation is left in the row of trees. By avoiding cross cultivation, a bench terrace is formed gradually. When the bench is completed, after some years of cultivation under irrigation, the trees stand part way down the steep downhill slope—the bank below the bench or platform—amply protected by vegetation (Fig. 58).

Fig. 58.—California bench terrace.

Before bench terraces are constructed in any area, thorough study should be made to determine if there is justification for cropping slopes so steep as to require this intensive method of protection. If suitable lands of less declivity are available or if advantageous return cannot be expected, the steeper slopes should be utilized for purposes not requiring cultivation. There are many parts of the world, however, where bench terracing undoubtedly is going to be required sooner or later, because of scarcity of more favorable land.

Take Puerto Rico, for example. Forty per cent or more of the arable land of that island has a slope of 40 per cent or

greater. Population exceeds 500 per square mile, and about 80 per cent of the people depend directly or indirectly on agriculture for a livelihood. In view of this heavy pressure on the land, it is apparent that an adequate soil conservation program in Puerto Rico must embrace control of erosion and conservation of rainfall on many steep slopes.

Fig. 59.—Modern bench terraces in Puerto Rico—in successful use for vegetables. (Work by Soil Conservation Service.)

The method employed by the Soil Conservation Service in constructing bench terraces in Puerto Rico is something like that used in California, except that in the case of the ordinary crops, the planting is done on the platform (the flat top of the structure) whereas the bank (the steep sloping part of the structure) usually is stabilized with adaptable plantings of grass or legumes (Fig. 59).

In the *Puerto Rican bench terrace* the outer edge of the platform is somewhat higher than the inner edge, so that drainage can be insured without allowing water to run over the bank.

An open ditch along the flow line, or inner edge of the terrace platform, conducts excess rainfall into a sodded outlet channel.

Inasmuch as relatively infertile subsoil material is often exposed in this type of terrace, due consideration must be given to the inclusion of humus-supplying legumes in the cropping rotations and the use of manure or fertilizer wherever the need is indicated.

The area of the cultivable portion of a bench terrace will decrease as the slope increases. For example, where the slope of the land is 30 per cent, the width of the platform, or cultivable area, will be 8.6 feet and the area of cultivable, or horizontal, land will be approximately 64 per cent of the total surface area, with 36 per cent included in the steep bank or riser. But where the declivity runs up to 80 per cent, the width of the horizontal area, or platform, will be only ½ foot wide, with only 10 per cent of the area cultivable, that is, with a 4-foot vertical interval in both instances. But if the vertical interval is doubled, the area of cultivable land would be largely increased.

Graded Terrace. The graded type of terrace appears to have been developed in the United States. It has been used far more extensively in this country than in any other.

Need for such structures, with their wide ridges and channels, variable grades, and careful spacing according to rainfall intensity, soil character, and slope of the field, is becoming generally recognized in the United States. In 1885, Priestley H. Mangum, a farmer living near Wake Forest, N. C., introduced a broad-base terrace by widening the narrow-ridged terrace that had long been used in the Southern states. Modifications of the Mangum terrace are used extensively today in many parts of the country.

Basic Principles in Terracing. Channel *grades* of more than 4 inches per 100 feet of length are seldom necessary or advisable. Frequently, the slope of a terrace channel is increased

every 300 to 500 feet in the direction of the outlet. In localities of high-rainfall intensities and soils of average absorptive capacity, a fall of 1 inch per 100 feet is commonly provided for the first 400 feet of channel length, then 2 inches per 100 feet for the second 400 feet, 3 inches per 100 feet for the third 400 feet, and 4 inches per 100 feet for the fourth length of 400 feet. In areas of low rainfall and soils of average absorptiveness, a common grade arrangement is to run the first 500 feet on the level and to give a fall of 1 inch per 100 feet for the second 500 feet and 2 inches per 100 feet for the third 500 feet.

Spacing. A fundamental principle in effective terracing is to locate the structures so that they will intercept the runoff from the area above each terrace channel before the velocity of the water has become great enough to cause appreciable erosion damage.

TABLE 8. RECOMMENDED TERRACE SPACINGS AND RELATED DATA FOR GRADED TERRACES

Per cent slope(s)	Vertical interval (VI) ft.	Horizontal distance, ft.	Acres per mile of terrace	Acres per 100 ft. of terrace	Ft. of terrace per acre
1	2.00	200.00	24.24	0.46	217.8
2	2.50	125.00	15.15	0.29	348.5
3	2.75	91.67	11.11	0.21	475.2
4	3.00	75.00	9.09	0.17	580.8
5	3.25	65.00	7.88	0.15	670.1
6	3.50	58.33	7.07	0.13	746.8
7	3.75	53.57	6.49	0.12	813.1
8	4.00	50.00	6.06	0.11	871.2
9	4.25	47.22	5.72	0.108	922.5
10	4.50	45.00	5.45	0.103	968.0
11	4.75	43.18	5.23	0.10	1008.8
12	5.00	41.67	5.05	0.09	1045.4

The spacing specifications given in Table 8 are for the graded type of terrace. For example, on a slope of 6 per cent, the

average distance between terraces would be about 58.3 feet on what might be considered average land suitable for terracing. Depending on the kind of crop, intensity of rainfall, erodibility of the soil, or other determining factor, this distance may be increased or decreased by an amount of not more than 15 per cent of that shown in the table. Thus, on a 6 per cent slope, there would be allowed a maximum distance of 67 feet and a minimum distance of 50 feet.

Cross Sections. The three main cross-section requirements of a terrace are (1) ample channel capacity to take care of the runoff, (2) side slopes gentle enough to avoid excessive erosion and to permit efficient operation of farm machinery without undue tearing down of the ridge, and (3) economical construction.

Customary cross-section specifications for both the graded and the level runoff-control and absorption types of terraces are shown in Graph 3.

The cross-section area of the terrace channel should seldom be less than 10 square feet (for example, a channel 4 feet wide at the bottom, 12 feet wide at the top, and 15 inches deep would have a cross section of 10 square feet). The water-carrying depth of a settled terrace should be from 15 to 20 inches, and the total width of the terrace from 15 to 40 feet, depending on the slope of the field and the type of farm machinery to be used. The side slopes of the channel or ridge should seldom be steeper than 4 to 1 (a fall of 1 foot in a horizontal distance of 4 feet), and 5 to 1 is preferable. On pasture or other non-cultivated land, smaller cross sections are usually satisfactory.

Length. Usually, 1,600 to 1,800 feet is the maximum distance that a terrace should carry water in one direction. Such long terraces should have a larger channel cross section. Where a longer terrace may occasionally be needed, it frequently can be

constructed by sloping the channel both ways from a high point along the terrace line.

Limiting Slopes. On slopes above 10 to 12 per cent, it usually is difficult to build and maintain graded terraces that have adequate channel capacity or that can be satisfactorily farmed over with modern machinery.

Planning Terracing Work. Terraces are most commonly used on sloping cultivated land where simple, less expensive measures will not provide adequate control of erosion. Too often, terracing is considered as a cure-all for the erosion problem. Terracing cannot be economically justified on land that can be protected adequately by such tillage and agronomic measures as contour cultivation, crop rotation, and strip cropping, except where used for conservation of rainfall or diversion of water in connection with gully control. These measures alone may provide sufficient protection under conditions of mild slopes, relatively low-rainfall intensities, and highly absorptive soils, especially where good crop rotations are practiced. But with highly erodible soils, long slopes, and high-rainfall intensities, agronomic control measures may give only partial control. Under such circumstances, agronomic measures need to be reinforced with terraces.

Reconnaissance. The first step in planning a system of terraces for a farm is to examine carefully the physical condition of the land. All such features as slope, ridges, hummocks, natural drainage-way depressions, field and property lines, roads, and buildings must be taken into consideration. Adjoining lands must be examined also to determine such relationships as the size and condition of the drainage areas contributing runoff to lands to be terraced, the vegetative cover, and available sites for disposal of excess water. Where the field to be terraced receives any considerable amount of runoff from adjacent higher land, it usually is good practice to divert this

water or part of it by some form of diversion or interception ditch, in order to prevent overtopping and breaking the terraces to be installed downslope.

In the preliminary planning, all necessary terracing for the entire farm should be considered at one time so that the system installed in one field can be fitted properly into the complete system for the entire farm without undue difficulty or expense. The practicability of rearranging fields, fences, and roads to conform with good terracing and land-use practices should always be carefully appraised.

Terracing usually is planned according to drainage units, that is, according to areas from which necessary water disposal can be satisfactorily handled through a single outlet. Where fields on adjacent farms lie within the same drainage unit, a coordinated joint terracing system often can be worked out for both fields where satisfactory arrangements between the landowners or operators can be made for construction and maintenance of the terraces and outlets.

Location of the most desirable terrace outlet and determination of the necessary measures for outlet stabilization are important items to be considered in developing the field plans. After the outlets are located, the terracing system should be developed around them in such a way as to conform to the topography and at the same time make most advantageous use of the outlets. The most simple and economical type of outlet is an area having a well-established sod or other protective cover over which water can be discharged without danger of cutting. Many terrace systems have failed because too much dependence was placed on natural outlets that had too little protective cover of grass, shrubs, or forest litter to withstand the concentrated discharge from the terrace channels. The ideal natural outlet consists of a dense sod protected from overgrazing or other damage. On moderate slopes, unburned

woods with a good cover of ground litter make a very satisfactory outlet.

Where adequate natural outlets are not available, stabilized waterways must be established, as by protecting the area with vegetation or structures (see Chap. 13 for further discussion of outlets).

Staking Terrace Lines. In laying out a terrace system, random stakes are first set out to mark the location and approximate width of the necessary outlet ditch or ditches. Then the upper terrace is staked, using the drainage divide as a starting point from which to measure the vertical interval for the first structure.

It is not always possible, even for experienced terrace engineers, to establish a satisfactory system in the first attempt. After a few lines have been staked, minor topographical features sometimes necessitate changes in the precise location of the terrace.

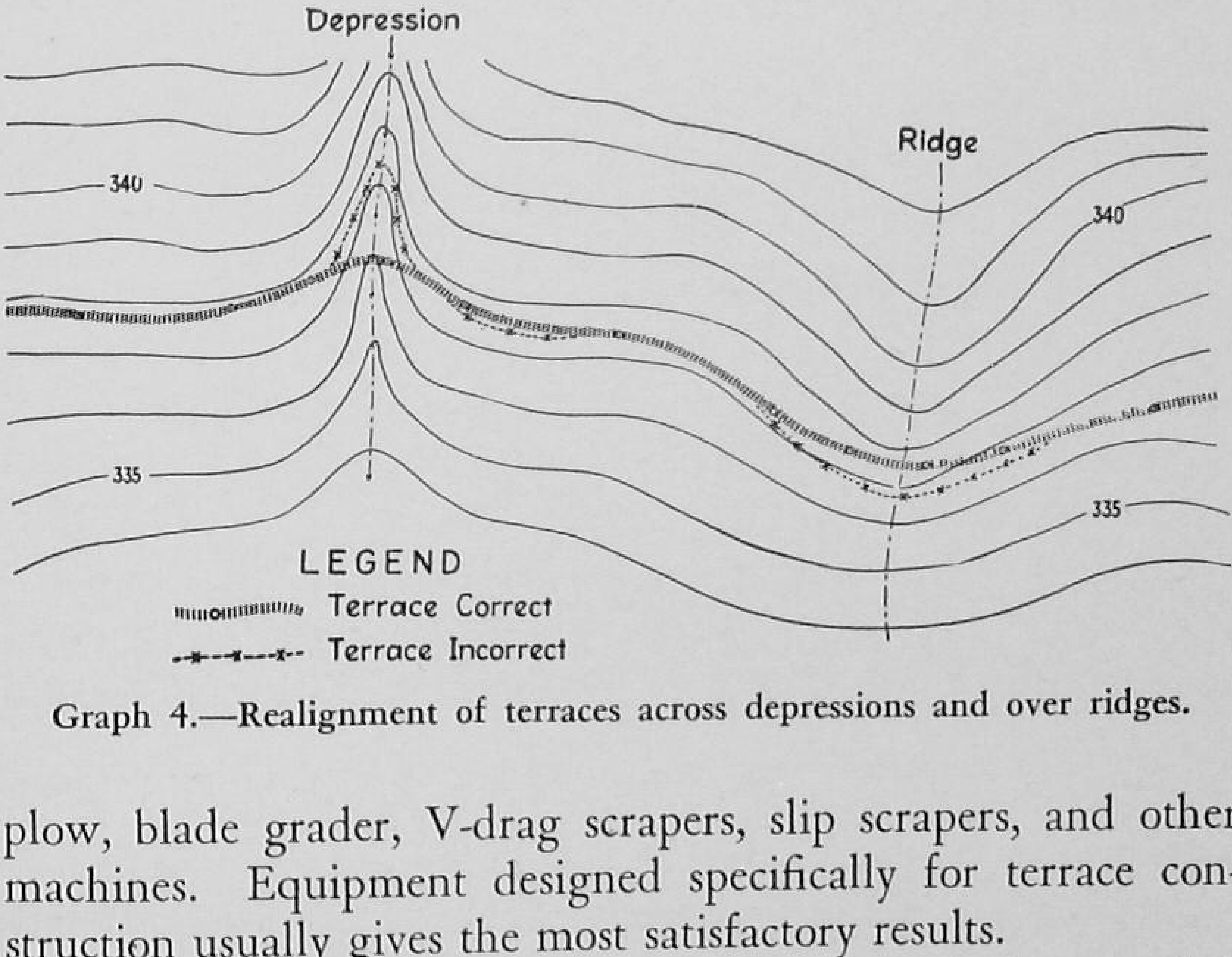
In order to get proper alignment, it usually is most convenient to start staking at the outlet end. Stakes should be set at intervals varying from 50 to 100 feet, except on curves and across depressions, where 25-foot spacings are often necessary. It is customary and usually most convenient to have the stakes indicate the location of the center line of the terrace ridge.

After all the terrace lines have been staked, some realignment is usually necessary on each terrace in order to eliminate sharp curves to provide easier construction and to develop a terrace that will offer least interference with farming operations. Good field judgment must be exercised to get best results. Graph 4 illustrates the principle of terrace realignment.

Realignment is usually done by moving certain stakes reasonable distances up or down the slope. Often such movement will, of course, be restricted by the drainage and construction features involved.

In order to facilitate construction, the final line of location should be marked with a plow furrow, since stakes are easily lost and are more difficult to follow with heavy terracing equipment.

Machinery and Equipment. In terrace construction, a wide variety of equipment is used, including the terracing plow, disk



Graph 4.—Realignment of terraces across depressions and over ridges.

plow, blade grader, V-drag scrapers, slip scrapers, and other machines. Equipment designed specifically for terrace construction usually gives the most satisfactory results.

Small-blade terracers, scrapers, V-drags, and plows pulled by farm tractors, horses, or mules are being used on many farms with good results.

In building terraces, all the earth may be moved from the upper side or a part from each side. The broad-channel type is built by moving most of the material from the upper side.

Where terraces cross gullies or even slight depressions, extra fill work must be done to maintain proper location and ridge elevation. A slip scraper, fresno, or rotary scraper is used

generally for such work (Fig. 60). Where even a small gully has developed, the fill should be made as impervious as an earth dam through proper placement of material and adequate compaction. A substantial bond between the fill and the gully sides always should be provided. The fill must be high and

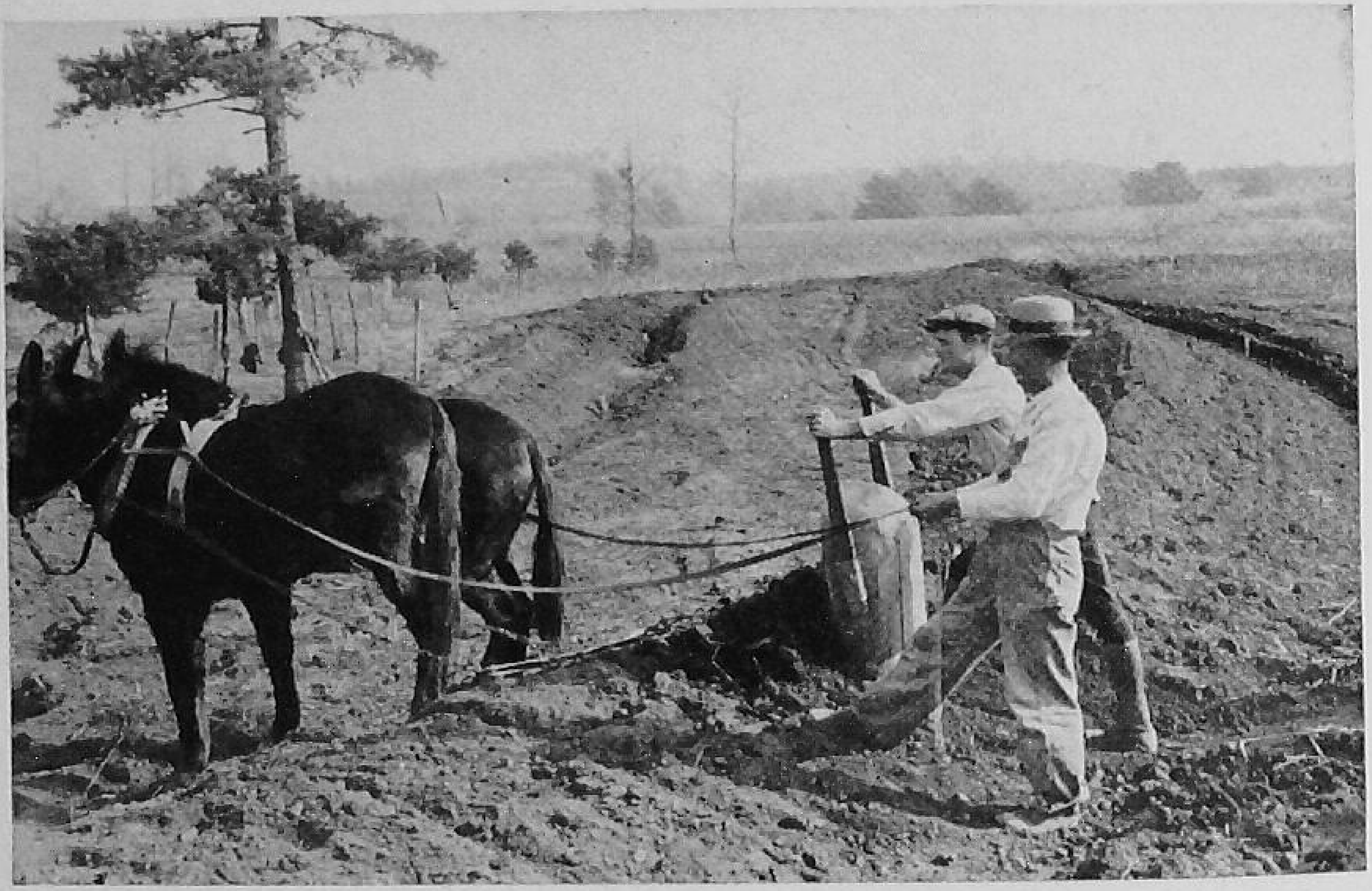


Fig. 60.—Slip scraper and team used to fill low places along terrace ridge.

wide enough to prevent overtopping. Usually, the height of the terrace at points where fills are made should be increased by 15 to 20 per cent to compensate for the extra settlement that will occur at such points.

Level Terraces. Level terraces are being used more extensively in dry regions to hold all possible rainfall for crop production.

Prevention of erosion, especially of soil blowing, by the level terrace is accomplished to a large degree indirectly through water conservation. The increased water held by such terraces makes the soil more resistant to wind erosion while encourag-

ing the growth of crops or other protective vegetation which also helps safeguard the land.

Construction. One of the most important points in the construction of level terraces is to make them so they will spread

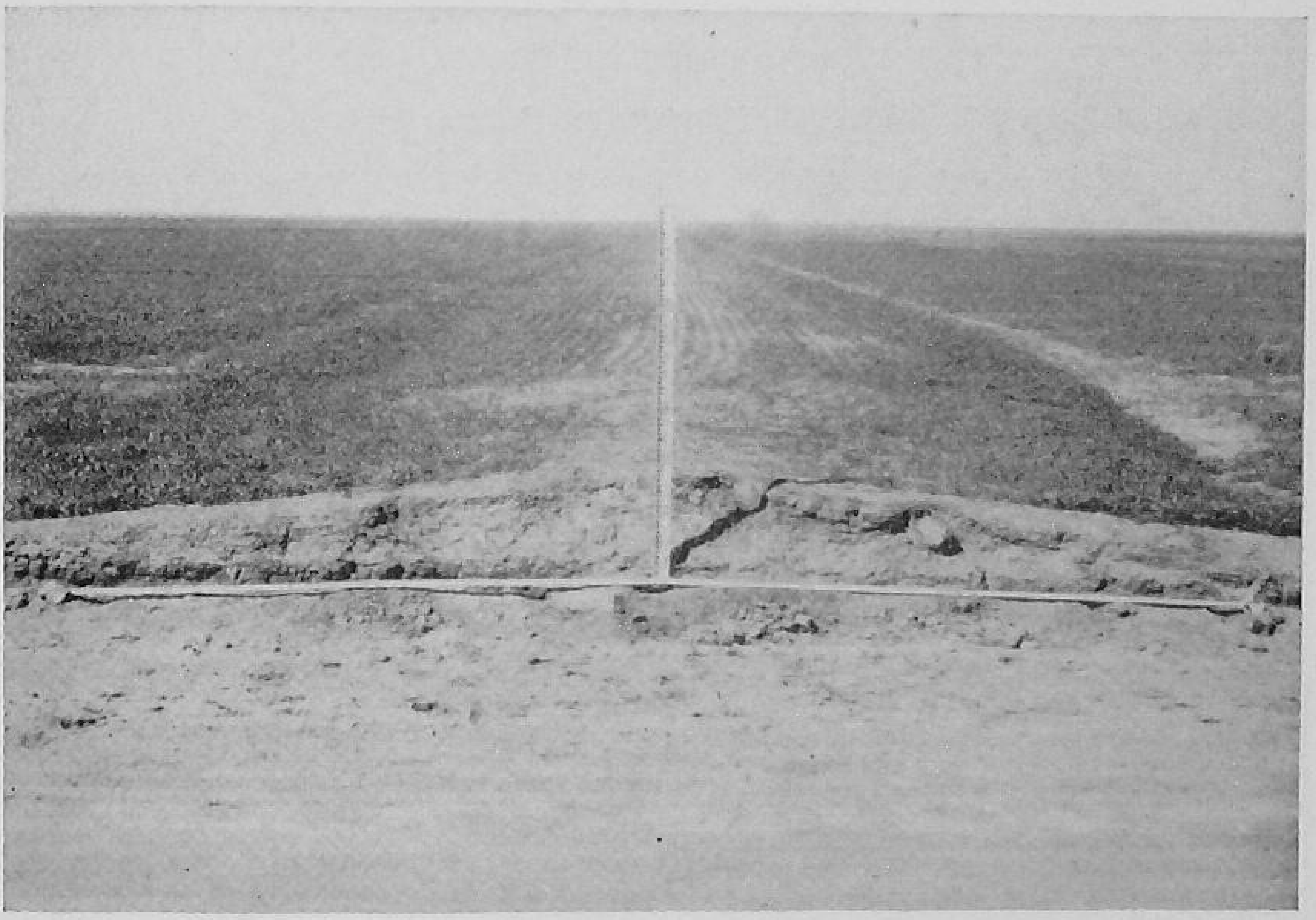


Fig. 61—Cross section of a level terrace in the Great Plains, western Kansas. The ridge projects well above the surface so as to spread the water over a wide area. The wide cross section is necessary to accommodate the large tillage machinery used in this region.

the impounded water over the widest practicable area. Generally, they are built on slopes of not over 3 per cent. The ridge is made high enough to spread water as far back as the next higher terrace where this is practicable (Fig. 61). Earth required for the terrace ridge is so excavated as to avoid concentration of the ponded runoff.

Construction of the terrace embankment from both sides is usually advisable, not only because of the gentle slopes but

because it is easier to attain the necessary height in this way. Where maximum ponding effect is desired, the structure must be designed with ample cross section and both ends must be closed. In general practice, however, the ends are often only partly closed so that excess rainfall can escape before the terrace ridge overtops. In some localities, the ends are left open, and special outlets are used to dispose of excess water.

Because of the nearly level topography where level terraces are built, irregularities in the terrace lines can be straightened out more easily than in the case of graded terraces.

Reasonably good results can be expected where the terraces are spaced so that the ponded water will extend from one terrace to the base of the next one above. With an 18-inch terrace on a 1 per cent slope, this would permit horizontal spacing at intervals of 150 feet. On steeper slopes, the water-storage capacity of level terraces with closed ends is often the limiting factor in determining spacings. This capacity should be sufficient to take care of the maximum accumulation of rainfall that ordinarily can be expected from the contributing drainage area.

Cultivation of the Terrace. The most desirable tillage practice for terraced land is contour farming. Operation of tillage equipment parallel to the terraces minimizes possibility of damage to both ridge and channel. Plowing parallel to the terrace ridge and regulating the location of dead furrows and backfurrows make terraces easier to maintain. In this way, the cross section can be changed to provide the most desirable slope for a given field. Cultivating across the terrace ridge flattens it out and soon calls for rebuilding. It generally is bad practice.

Where it is not possible to maintain proper cross sections with regular plowing operations, it will be necessary to use a blade or scraper at more or less regular intervals. For this

purpose, lighter terracing machines or homemade V-drags drawn by ordinary farm power generally will do a satisfactory job.

Questions

1. What is the purpose of a modern field terrace?
2. Define the principal types of terrace.
3. Under what conditions is bench terracing justified?
4. How does declivity affect the cultivated portion of a bench terrace?
5. What are the principal limitations in the use of graded terraces?
6. Define briefly the major steps necessary in the construction of a graded terrace.
7. What is the principal objection to the level terrace? How does it differ from the graded terrace in applicability?
8. What are the principal tools used in the construction of graded and level terraces?
9. Under what conditions will a graded terrace suffice for control of erosion?
10. Under what conditions will a graded terrace need the support of other conservation measures?
11. How should a terrace be cultivated?
12. Describe the Mangum terrace, "California" terrace, "Puerto Rico" terrace.
13. What principal considerations determine proper development of a terrace system?

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CHAPTER 13

Channels and Outlets

PRESENTING:

Natural Outlets
Mechanical Outlets
Meadow Strips
Seeding and Sodding Outlets
Protecting Outlets

Although much study has been devoted to the construction of terraces, too little attention has been given to the disposal of water at the ends of the structures.

To insure proper discharge, the bottom of the outlet channel should be a few inches lower than the end of the terrace channel. The outlet here should be sloped at a grade which when sodded will prevent cutting back into the terrace channel.

Natural Outlets. Natural drainage ways, as swales and streamlets, often serve admirably as outlets for terraces and other artificial waterways. More frequently, however, efficient outlets have to be established by stabilizing ground conditions or constructing safe channel ways.

Vegetation, in the form of strips or solid covers of grass or other thick-growing plants as well as plantings of trees, vines, and shrubs, is being extensively and effectively employed in the protection of outlets for runoff (Fig. 62). Water from terraces, diversion ditches, and other field or pasture channels generally can be discharged safely over a firmly vegetated slope. Broad, shallow, vegetated depressions usually are preferable to narrow,

Fig. 62.—Upper, control of water by combination of meadow strip and Bermuda sod baffles, South Carolina Piedmont. In this region Bermuda grass will protect a properly prepared outlet channel flowing 6 to 9 feet per second, depending on the gradient and condition of the grass. Lower, showing high resistance of Bermuda grass to erosion.

deep depressions or vegetated channels. Where covers of grass or legumes are used as stabilizers, the broad, shallow outlet or waterway is referred to as a *meadow strip* (Fig. 63) or *pasture strip,* according to the use made of the forage.

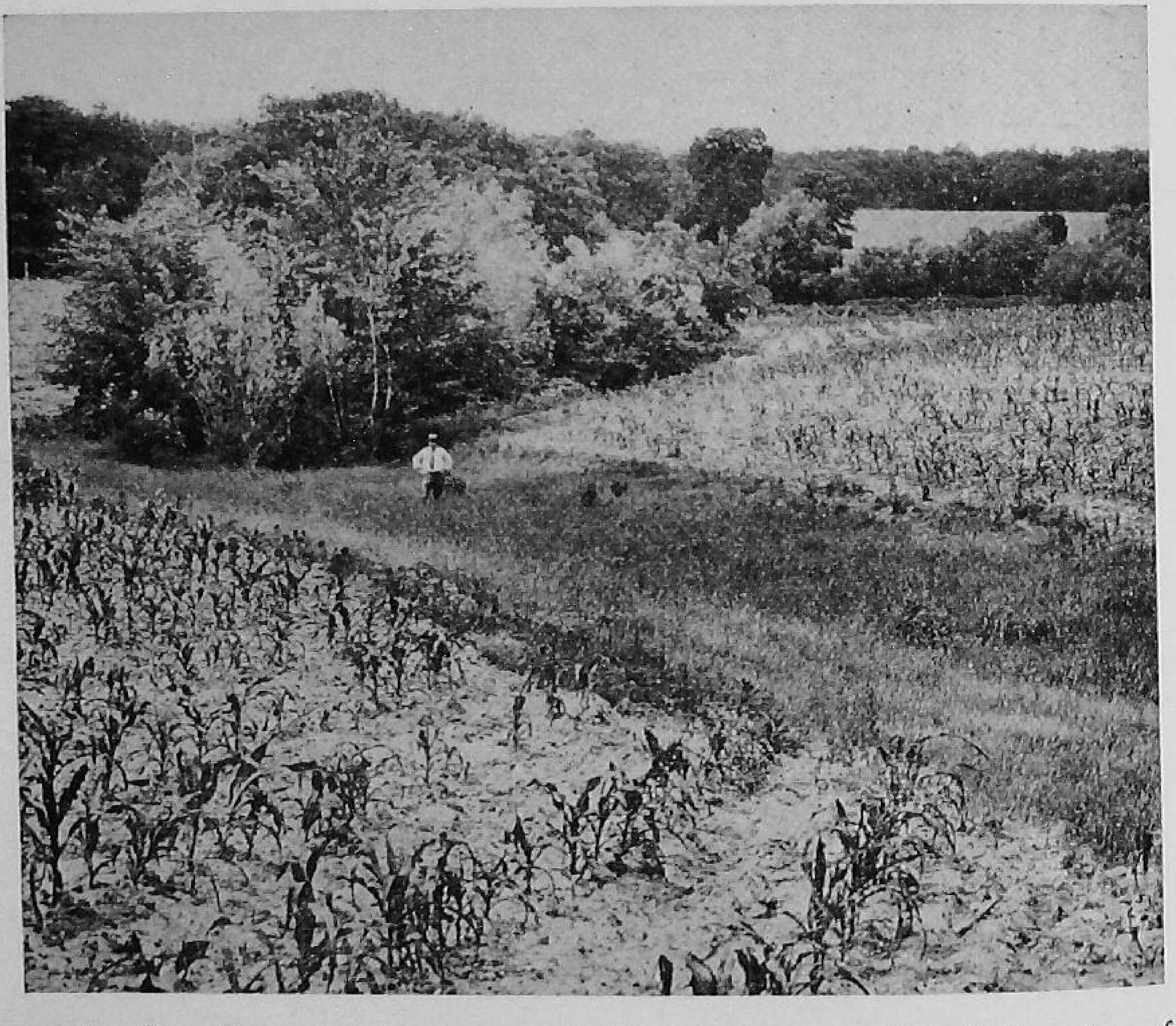

Fig. 63.—Vegetated depressions of this kind are capable of disposing of large quantities of runoff from terraces and contoured rows without danger of gullying. They frequently make the best meadows on the farm.

Specially constructed vegetated channels are necessary in many fields and in some pastures where natural depressions suitable for meadow or pasture strips are not available. Because of increased velocity and depth of flow caused by the restricted size of such artificial channels, considerable caution is necessary in their design, construction, and stabilization.

Mechanical Outlets. The use of mechanical outlets usually is limited to terracing systems and diversion ditches. Soil and climatic conditions unfavorable to the growth of suitable vegetation, however, may make it necessary to use them locally for practically all water-disposal purposes.

Low-velocity channel ways are made by using a series of drop-check structures (small dams) at intervals along the channel to reduce the grade. These slow the flow of water and prevent scouring. High-velocity channels are made by installing a continuous lining of an erosion-resistant material, as masonry, asphalt, cement, or metal.

In planning channel and outlet systems, it is always necessary to consider the relation of the outlet whether on the same farm or adjacent land. Because of interference by farm roads, fences, buildings, property lines, and topographic features, such installations usually develop a variety of unforeseen difficulties.

Unprotected Gullies and Roadside Ditches Should Not Be Used. Roadside ditches and expanding gullies should be avoided as terrace outlets except where they have been effectively stabilized. It is sometimes desirable for farmers to co-operate with highway-maintenance officials in working out satisfactory ways for disposing of runoff from both terraces and highways. Similarly, it is frequently advantageous for two or more landowners having terraced fields within the same drainage unit to arrange for a common outlet system and its permanent maintenance.

It is always important to determine the most satisfactory location for both terraces and outlets in advance of construction because, once established, relocation is a costly and difficult procedure.

The simplest and most economical type of outlet for terraces and diversion ditches usually is an established sod or other vegetated area that will withstand the impact of rushing water.

Although a good pasture or meadow sod generally gives the best results, unburned, ungrazed woodland, particularly on moderate slopes, can be used satisfactorily.

Meadow Strips. Natural depressions stabilized with resistant stands of grass or legumes make very efficient outlets as well as good pastures and hay lots. For such *meadow strips,* wide, shallow depressions having slopes not exceeding 5 or 6 per cent are preferable. The width required for efficient results will depend on the slope and the size of the area drained. Generally, a minimum width of 1 foot should be provided for each acre within the contributing watershed. Meadow strips should not be less than 100 feet wide, since narrower areas generally cannot be used satisfactorily for grazing or hay production. One of the principal difficulties with meadow strips is the common tendency to make them too narrow.

Often, gullies partly filled by sloping the banks are used as water-disposal channels by establishing good stands of grass or legumes or mixtures of the two. Thus, useless and dangerous gullies are converted into essential waterways, which often are further utilized for grazing or hay production.

When suitable natural outlets are not available, vegetated channels are resorted to in those localities where an adequate stabilizing sod can be established and maintained. It is important that the cross section of such artificial waterways be designed to prevent flows of scouring velocity. The amount of water that can be carried safely by such a channel is limited by the gradient, the cross section, and the permissible channel-flow velocity (usually not more than 5 to 8 feet per second). When larger amounts of runoff must be disposed of, two or more parallel channels can be provided.

Mechanical protection is sometimes used to supplement the efficiency of vegetated channels. Weak points, particularly toward the lower ends, often call for some measure of mechani-

cal support. Sharp drops, as at the head of gullies, often require structures to moderate the impact of water.

Seeding and Sodding Outlets. It is both hazardous and expensive to undertake establishment of vegetated outlets at the same time that they are being used for the discharge of water. Seed, fertilizers, and young plants are washed out readily unless special precautions are taken. Sometimes the placing of sod over the entire channel or in strips across it will provide adequate protection, but this is more costly than ordinary seeding. Moreover, it is difficult to anchor newly placed sod in some channels.

In various localities, sod has been established successfully on seeded outlets with the aid of a mulch of straw, brush, or old hay applied at the rate of 2 or 3 tons per acre and anchored with wire or other means. A good mulch not only protects the seedbed from erosion but aids in the conservation of enough moisture to encourage germination and growth of the grass.

The use of strip sodding generally is restricted to moderate slopes (5 per cent or less) and to relatively small drainage areas (watersheds of 15 to 20 acres or less) where the volume of runoff is not large. Even with these limitations, however, there occasionally are failures.

Spot and broadcast sodding are used to establish Bermuda grass from root stolons. Spot sodding is accomplished by planting root sprigs in handmade holes, spaced on 12- to 24-inch centers, with 2 to 3 inches of soil packed around the roots.

Tests made at the Soil Conservation Service outdoor hydraulic laboratory have shown that in the vicinity of Spartanburg, S. C., Bermuda grass, for example, will effectively resist erosion in waterways for velocities varying from 6 to 9 feet per second, depending on the gradient of the channel and conditions of the grass—whether green, dormant, long, or short.

Various grasses and legumes extensively grown in that region withstand, without erosion, velocities as follows: centipede grass, 8 feet per second when dormant and 9 feet when green; crab-Dallis grass mixture, 3½ feet per second when green;

Fig. 64.—The use of temporary structures in runoff channels generally gives insufficient protection from erosion.

kudzu, 2½ to 4 feet per second, depending on whether dormant, green, cut or uncut; common lespedeza, 1 to 7 feet per second, depending on same conditions mentioned above; and Lespedeza sericea, 2½ to 5½ feet per second, depending on same conditions.

Bluegrass and a timothy-redtop mixture, tested near McCredie, Mo., withstood a velocity of 7 feet per second.

Protecting Outlets. Where mechanical protection is necessary in terrace outlets, low permanent structures of the weir-notch type generally are used. Temporary structures usually have proved ineffective (Fig. 64).

Notch dams may be built of brick, stone, reinforced concrete, precast concrete blocks, or a combination of these materials. The local availability of materials frequently will determine the type of structure used. In order to provide a more stable structure and eliminate danger of cracking, reinforced concrete is preferable for the apron slab and cutoff walls, regardless of the kind of material used in other parts of the structure.

The following quotation from "Terrace Outlets and Farm Drainageways," *Farmers' Bull.* 1814, is highly pertinent to the hydraulics of outlets:

> In the design and construction of all channels for the conveyance of runoff, certain fundamental hydraulic principles must be observed in order to assure satisfactory results. The size of drainage areas and the rates of runoff to be expected should be determined. Dimensions and velocities of drainageways also have to be computed. Drainageways must be made large enough to carry the runoff during heavy storms without overtopping, and they must be constructed so as to avoid undesirable channel velocities.

Questions

1. What is a runoff outlet?
2. What are the advantages of using natural depressions to dispose of excess runoff?
3. Give examples of the need for mechanical outlets and some basic considerations in the use of structures.
4. Name an objection to use of unprotected gullies and roadside ditches for disposal of runoff.
5. What is a meadow strip? What relation does size of a watershed have to the width of a meadow strip?
6. Why should runoff-disposal outlets be stabilized in advance of use?

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CHAPTER 14

Gully Control

PRESENTING:

- Types of Gullies
- Methods of Gully Control
- Diversion of Runoff
- Conveying Runoff through Gullies
- Artificial Revegetation
- Stabilization with Structures

Types of Gullies. Gullies can be classified into two broad groups: *channel* and *waterfall.*

Channel Gullying. Vastly more gullying has had its beginning in artificial channel ways, as furrows, stock trails (Fig. 65), and natural depressions stripped of cover, than in any other way. If not checked, runoff concentrates in such depressions and either slowly or rapidly causes incisions of various shapes and depths, depending principally on soil (and subsoil) conditions, gradient, rainfall, and size and condition of contributing watershed. The depth and shape of channel gullying depend chiefly on the soil. If the underlying materials are soft and easily incised to great depths, deep, straight-walled, U-shaped gullies are formed. Where the subsoil consists of relatively unabsorptive clay, shallow, V-shaped gullies are the usual result. Where hard rock occurs near the surface, the incisions will be shallow and usually wide. Other variations are met with, but these major forms illustrate the influence of the material that is cut into to form gullies.

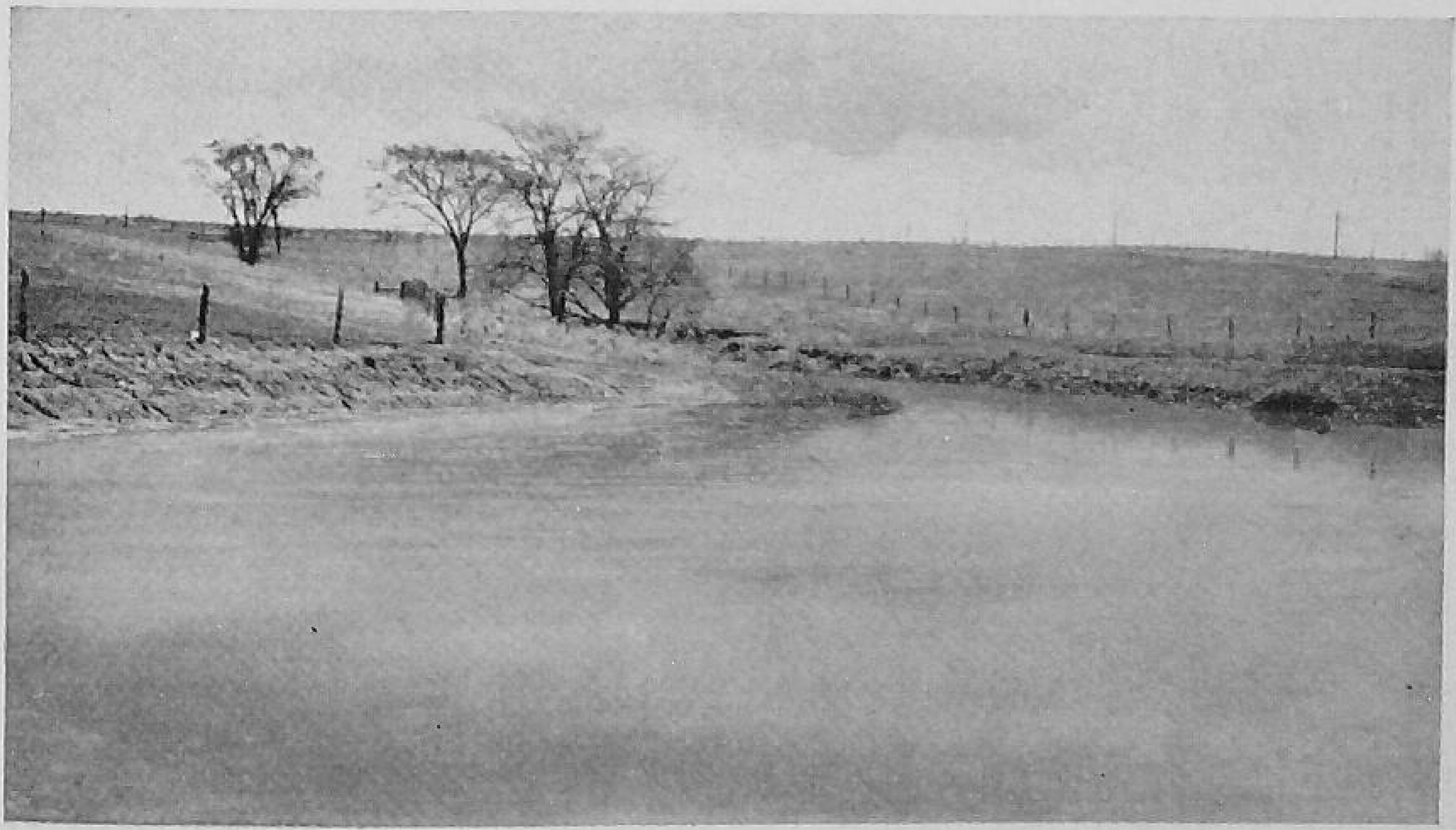


Fig. 65.—Above, a Missouri gully eating its way back into an overgrazed pasture; below, same gully controlled and converted into a stock-water pond.

Waterfall Gullying. Waterfall gullying (Fig. 66) is responsible for the formation of many of the deepest and widest gullies. It is also responsible for the branching of many gullies —the cutting out of tributaries, which have their beginnings

Fig. 66.—Sheet erosion in a Maryland corn field cultivated up and down the slope and beginning of a gully by undercutting waterfall at lower slope.

at vulnerable points along the sides. The points where livestock habitually enter and leave a ravine, for example, are especially vulnerable.

A small vertical overfall beginning at the lower end of an eroding depression wears away the underlying material until the top caves in. Continuing by the same process, the waterfall gradually extends the gully upslope. As the point of over-

fall advances in this manner, the height of the vertical drop usually increases, since the water cuts deeper and deeper in its effort to maintain a relatively flat grade at the bottom.

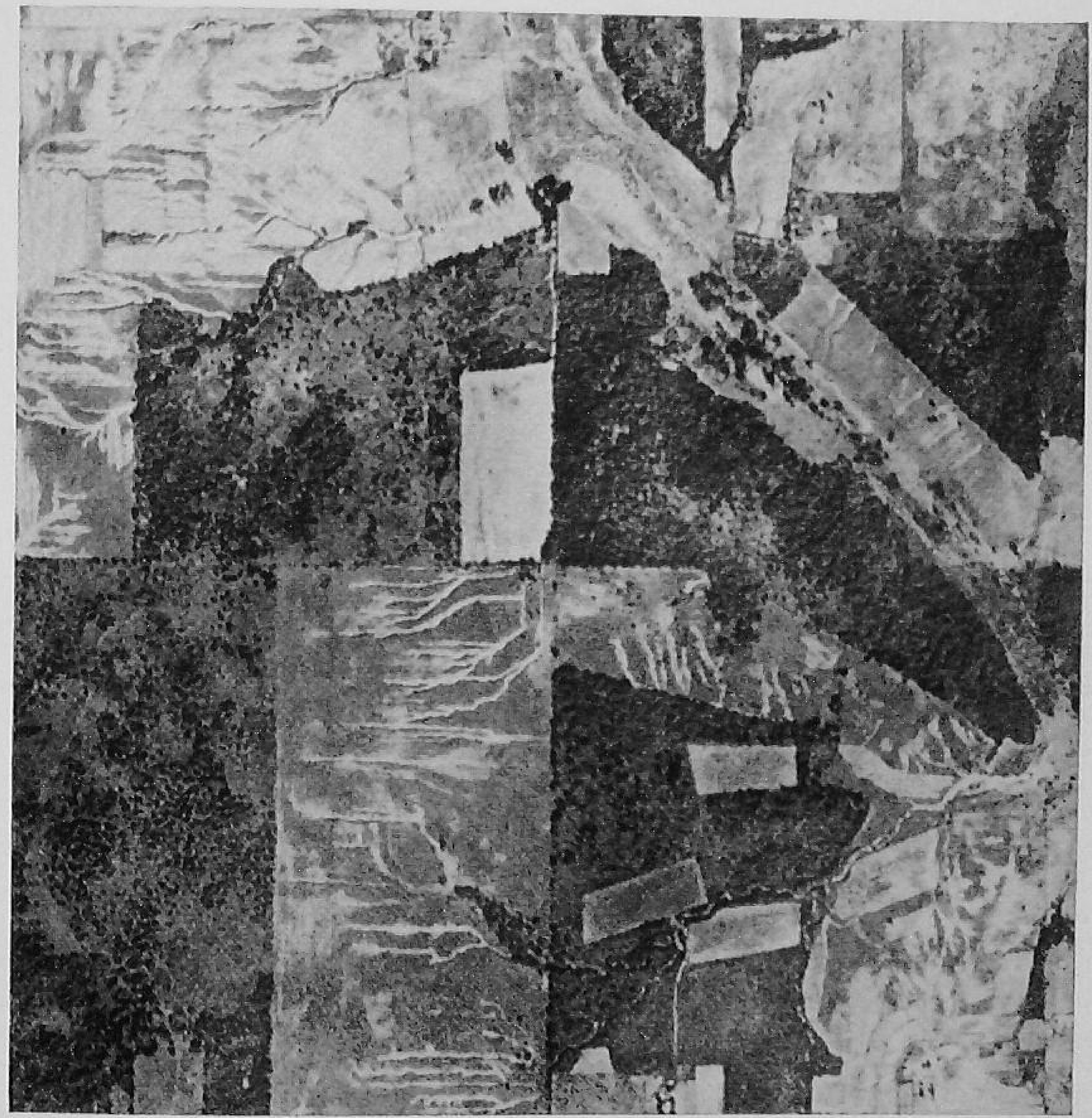


Fig. 67.—Straight pattern of gully erosion caused by cultivation up and down slope. Aerial photo of abandoned Oklahoma fields (640 acres all together.)

Often a series of parallel gullies crossing fields of uniform slope mark the sites of furrows (Fig. 67), ditches, wagon-wheel ruts, or livestock trails. More often, however, topo-

graphic variations, subsoil conditions, and the location, size, shape, and use of upslope clearings cause marked irregularities in the direction, shape, and size of the ravines.

It is easier to prevent the development of gullies than to control them after they have formed. Gullying usually is pre-

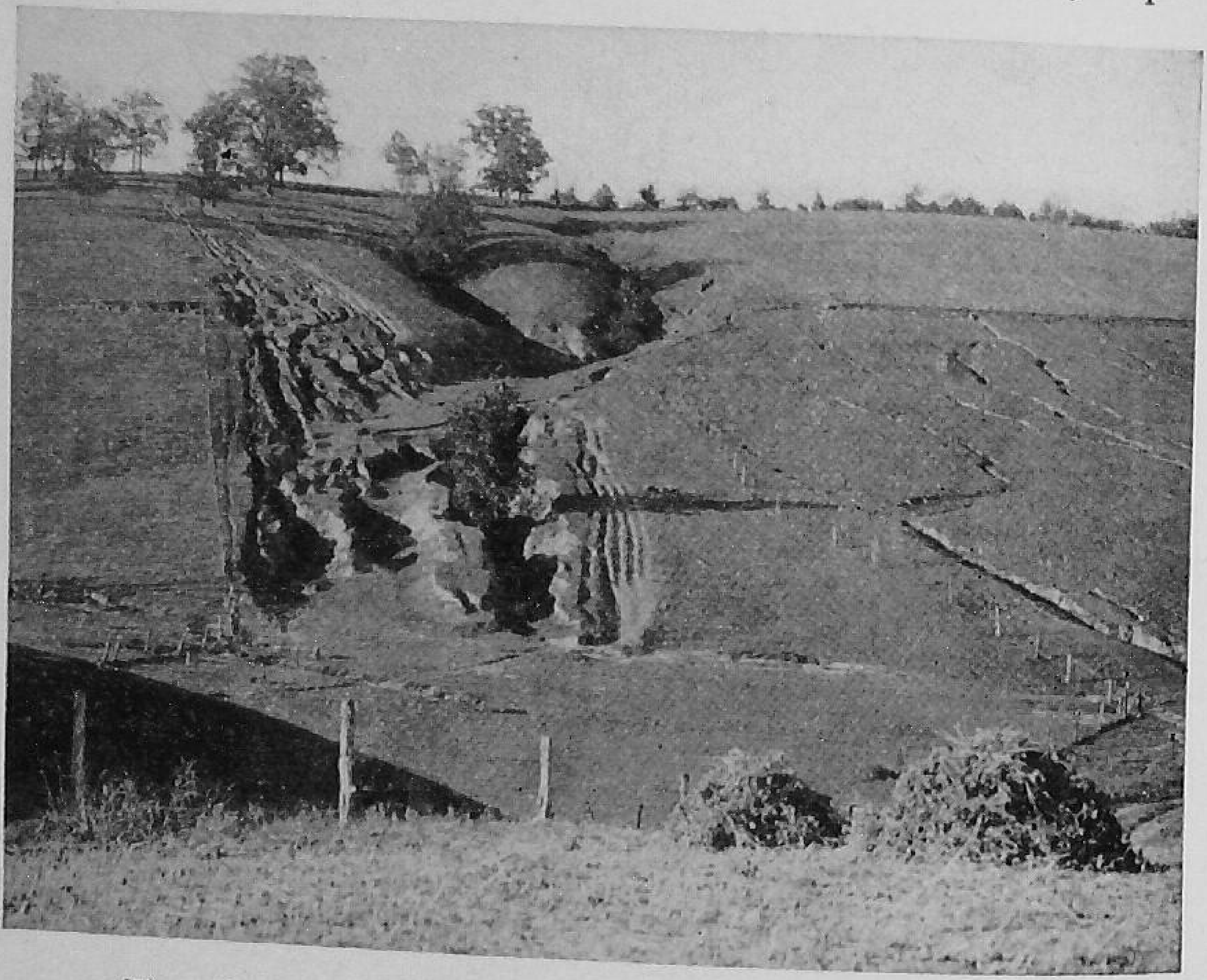


Fig. 68.—Gullies that started in sheep trails. Wisconsin.

ceded by sheet washing and therefore may be prevented to a large extent by taking the steps necessary to check such surface washing. However, constant precaution is necessary on sloping land to prevent the formation of gullies through the enlargement of minor channels formed by farm roads, wheeled machinery, livestock trails (Fig. 68), temporary drainage ditches, and the excavations of rodents. Usually, rather simple measures, such as the relocation of roadways as nearly as pos-

sible on the contour, development of minor ridged checks across roads, filling of ruts and rodent tunnels with straw or rock, and the relocation of fences in order to shift stock trails are sufficient to check many incipient gullies, if used in time.

When the cost of gully control exceeds the value of the land protected, the work may not be justified unless it serves to protect adjacent land, reservoirs, waterways, buildings, bridges, highways or other downstream property. After a gully has eaten its way to the head of a watershed, activity usually ceases. If it is merely protected from livestock, volunteer vegetation generally will establish a suitable protective cover. But when a gully starts advancing up a watershed slope, there is immediate necessity for employing intensive control measures.

Methods of Gully Control. Usually a good way to control a gully is to plant the entire ravine to stabilizing vegetation. However, even where it is impractical to plant the entire gully, generally the head must be stabilized. The type of vegetation and the procedure necessary for its satisfactory establishment will vary considerably according to soil, climate, and topographic conditions.

Runoff on a gullied field, however, must be handled carefully, particularly during the period when stabilizing vegetation is being started in or around the gullies. This runoff hazard increases with the size and condition of the watershed. A heavy concentration of water in a gully under treatment would damage or wash out the plantings. Temporary dams, porous brush or wire barrages (sometimes called *porous dams*), and diversion channels will help in many places in the establishment of satisfactory growths. If the volume of runoff is too great for effective vegetative control, permanent structures must be utilized, including especially the use of diversions to prevent runoff from entering the head.

From the standpoint of economy and practicability, the principal methods of handling runoff for gully control, in order of importance are the following: retention of as much of the rainfall as may be practicable on the watershed, diversion of runoff away from the gully, safe conveyance of runoff through the gully.

Frequently, the most practical solution will be a combination of these methods. Whatever method is used should be planned and executed carefully. Haphazard work will lead to failure or even to an aggravation of the gully conditions. Until vegetation is well established, it is very important to exclude livestock from treated areas, whether vegetation or structures are used.

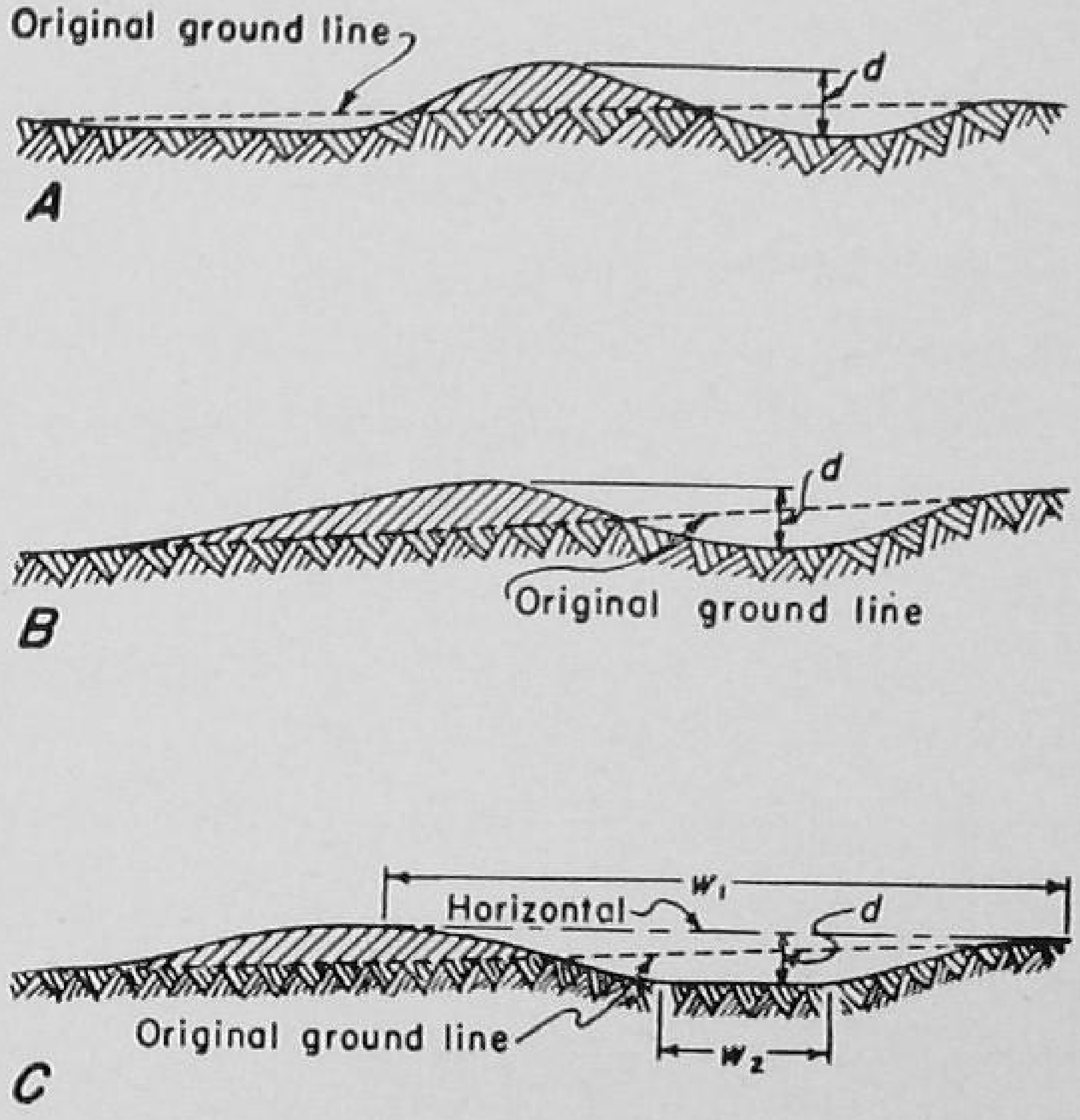
Generally, runoff of rainfall can be reduced materially through the use of ordinary soil and water conservation measures, previously explained.

Small and medium gullies with small to medium uncultivated watersheds frequently can be stabilized by placing a series of earth fills, spaced according to the steepness of the land, across the gully channel, with grass or other holding vegetation established as quickly as possible.

Diversion of Runoff. In the control of gullies, runoff usually should be diverted from the head of the ravine before control measures are installed within the channel. By terracing the drainage area above the gully head, much or all of the runoff can be diverted to another point for safe disposal.

Diversion channels are especially useful for gully control where the watershed is timbered or grass covered. Such structures generally are not effective immediately below unprotected cultivated fields unless a permanent *filter strip* of vegetation is established above the ditch to reduce velocity and silt load of the runoff.

It is essential that diversion ditches be made large enough to carry all the runoff from the contributing drainage area during periods of maximum rainfall. It is also necessary that the gradient and dimensions of the channel be such that the



Graph 5.—Diversion-ditch cross sections: A. Terrace-type diversion ditch for gentle slopes. Construction from both sides. Minimum value of "d" about 18 inches. B. Terrace-type diversion ditch for steeper slopes. Construction generally from the upper side only. Minimum value of "d" about 18 inches. C. This type of diversion ditch is suggested for watersheds exceeding 10 to 12 acres, especially for the steeper slopes. Minimum value of "d" should be 22 inches. Side slopes should be at least 3 to 1 where land slopes permit. (See Farmers' Bull. 1813, U. S. Dept. Agr.)

runoff will move through the ditch at nonerosive velocities.

Where the watershed is fairly well grassed, the gradient of earth channels without a permanent vegetative cover should not exceed 12 inches per hundred feet of length; but with a permanent lining of resistant sod, somewhat steeper gradients may be used. It is likely that these steeper gradients will

permit serious scouring if the vegetative protection of the channel is ever destroyed, and they should be used only where the cover can be depended on during periods of most severe runoff.

The terrace type of diversion ditch is being used extensively where the area of the watershed does not exceed 5 or 6 acres. On comparatively gentle slopes, this type of diversion ditch is constructed from both the upper and the lower sides; but on steeper slopes (steeper than 4 per cent), construction is generally from the upper side only. There are, of course, many variations from the indicated cross sections, because of local variations of soil, slope, and rainfall intensity.

It is highly important that the ditch be constructed with ample capacity to handle the maximum expected volume of water. The settled depth of the water channel should seldom be less than 18 inches. A minimum water cross-sectional area of 7.5 square feet is suggested for watersheds of 1 to 5 or 6 acres. Watersheds of 6 to 10 acres will require a channel depth of at least 24 inches and a minimum cross section of 12 square feet. For larger watersheds, cross section *C*, shown in Graph 5, is suggested, especially on steeper slopes.

The diversion ditch should be set back from the gully head a minimum distance of three times the height of the gully overfall.

Conveying Runoff through Gullies. The establishment of protective vegetation in a gully is usually much more difficult if runoff must be handled through the channel at the same time that the plants are being started.

Where mechanical measures are required for satisfactory control, permanent structures, such as masonry check dams, flumes, or earth dams reinforced by vegetation, should be provided to convey the runoff over critical portions of the ravine.

Gullies generally cannot be controlled adequately, however, until a vegetative cover is established over much or all of the

exposed parts of the ravine. From the standpoint of control, there frequently is little choice among trees, shrubs, vines, or grasses, because all these types of vegetation provide good protection when well established. Often, however, it is easier to establish satisfactory covers of trees, vines, and shrubs on gul-

Fig. 69.—A Georgia gully, originally 35 feet deep, being clogged by kudzu.

lied areas because of the slowness with which most grasses take hold on the poor subsoil commonly exposed in the ravines. Nevertheless, when grass is established, it will withstand greater water velocities and consequently be able to carry more runoff. Grasses are also more satisfactory than trees, vines, and shrubs as a reinforcement to structures.

In many instances, natural revegetation will provide a satisfactory cover if the gullied area is protected from livestock. Quite often, fencing livestock out of the ravine will be all that is needed for the establishment of a satisfactory growth of

volunteer vegetation. This opportunity to provide a protective cover at low cost is overlooked frequently, and unnecessary expenditures are made for structures or for planting.

Fig. 70.—A West Virginia gully stabilized by a combination growth of walnut trees and bluegrass.

Artificial Revegetation. Among the plants that have been used successfully in the reclamation of gullies are: trees and shrubs—black locust, willows, pines, honey locust, poplars, eucalyptus, tamarisk, wild plum, and buckbrush; legumes and vines—clovers, alfalfa, sweetclover, lespedezas, kudzu (Fig. 69), Virginia creeper, dewberry, blackberry, and raspberry; grasses

—Bermuda, bluegrass (Fig. 70), Johnson grass, centipede grass, redtop, orchard grass, brome grass, Sudan grass, Kikuyu, and wheat grasses. Various other plants are used in different localities.

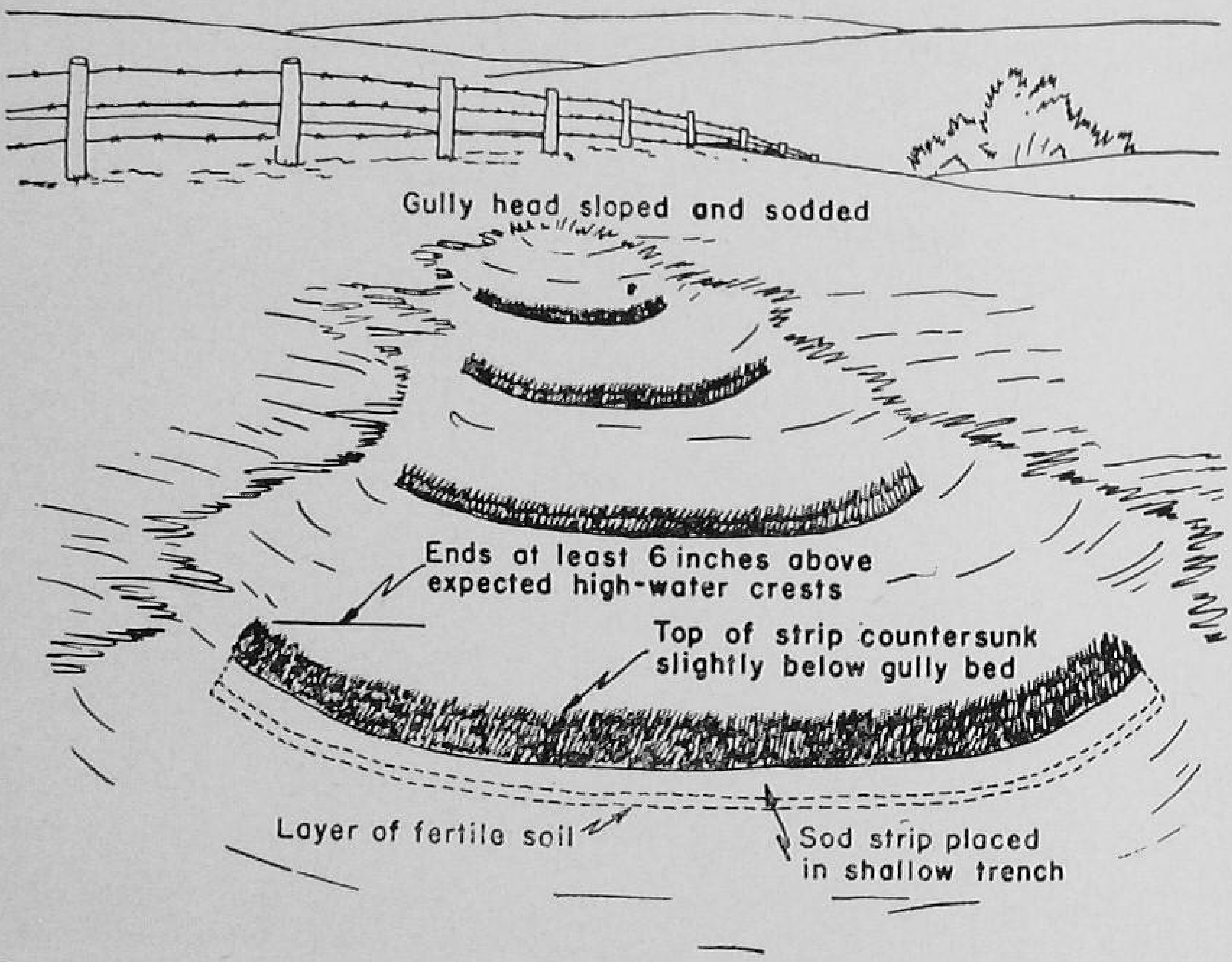
In gully plantings, it is frequently necessary to slope the banks before most efficient results can be obtained.

Fig. 71.—Gully head controlled by complete sodding (vegetated flume).

Occasionally, where suitable sod is available, it may be desirable to make use of the sodding method to stabilize some gullies or parts of them. Generally, however, this method is too costly for extensive use.

Sod flumes (Fig. 71) may be used effectively to control overfalls in gullies where the drop is less than 10 feet and the contributing drainage area is not greater than 25 acres. Where overfalls are not so high, larger watersheds may be considered. Bermuda and bluegrass sod have proved highly effective in adaptable localities.

The *sod-strip check* is suitable for small gullies with mild channel gradients (Graph 6) and watersheds of small to medium size. The strips should be placed across the channel so that each lies flush with or slightly below the bed of the



Graph 6.—Series of sod-strip checks in small gully. Such checks not applicable to gullies with steep grades.

gully. The strips should have a minimum width of 12 inches and should extend up the gully sides at least 6 inches above the level of expected high water. The spacing will depend on the drainage area, the gully gradient, and the spreading characteristics of the sod being used. Intervals of 5 to 7 feet commonly are used.

Stabilization with Structures. Structures are used in gully-control work either to facilitate the establishment of vegetation or to provide protection for those critical sections which

cannot be adequately protected by other measures. Where temporary structures are used, they are intended to function only until the vegetation becomes well enough established to provide necessary protection. *Check dams* of this type usually are made of brush, wire, poles, or loose rock. Where it is necessary to make use of mechanical structures as permanent reinforcements, they should be made of such durable materials as reinforced concrete, masonry, metal, or earth.

Temporary check dams thrown up across the bed of a gully have two uses: (1) to collect enough soil and water to insure the eventual growth of protective vegetation and (2) to check head or channel erosion until sufficient stabilizing vegetation can be established at that critical point. Where runoff from the contributing drainage area is diverted from or retained on the watershed or where the gully has advanced to the drainage divide, any check dams in a gully would be used primarily for the first purpose. Frequently, piles of closely compacted rock and brush across the bottom of a ravine will collect soil and water in a satisfactory manner.

Where temporary structures have been used in gully-control work, it has been found that several low check dams are more desirable than one large structure. Low dams are much less subject to failure than high ones; and after they silt up and rot away, they can be better protected from overfalls with vegetative cover. A temporary dam rarely should have an overfall height of more than 15 inches, and an average effective height of about 10 or 12 inches usually will be more satisfactory.

Temporary dams are especially adapted to gullies with small watersheds. They should be extended far enough into the bottom and sides of the gully to prevent washouts underneath or around the ends and should have sufficient spillway capacity to convey the maximum expected runoff. Generally, an apron

will be needed to protect the structure from the undermining action of water discharged from the spillway.

The life of a temporary structure, of course, will depend on the quality of the materials and efficiency of construction; but under ordinary conditions, they should last from 3 to 8 years. Spillway capacities usually are designed for the maximum rainfall intensities that may be expected over a 5- to 10-year period. The requisite capacity, or *spillway notch,* can be determined in the field by estimating the probable rate of runoff on the basis of the size and nature of the watershed. Table 9 gives the spillway dimensions required for various discharge rates; but as a factor of safety, the notch generally should be made several inches deeper than the indicated depth necessary to avoid overtopping. The notches should be as wide as practical in proportion to depth, in order to avoid unnecessary concentration of runoff as it passes over the structure.

TABLE 9. APPROXIMATE DISCHARGE CAPACITY IN CUBIC FEET PER SECOND OF RECTANGULAR NOTCHES IN SMALL CHECK DAMS

Depth of notch D, ft.	Spillway length, L, required for various discharges indicated, ft.												
	Cubic feet discharge per second	2	4	6	8	10	12	14	16	18	20	22	24
0.5		2.3	4.5	6.8	9.1	11.3	13.6	15.8	18.1	20.4	22.6	24.9	27.2
1.0		6.4	12.8	19.2	25.6	32.0	38.4	44.8	51.2	57.6	64.0	70.4	76.8
1.5		11.8	23.5	35.2	47.0	58.8	70.5	82.3	94.1	105.8	117.6	129.3	141.1
2.0		18.1	36.2	54.3	72.4	90.5	108.6	126.7	144.8	162.9	181.0	199.1	217.2
2.5		25.3	50.6	75.9	101.2	126.5	151.8	177.1	202.4	227.7	253.0	278.3	303.6
3.0		33.3	66.5	99.8	133.0	166.3	199.5	232.8	266.0	299.3	332.5	365.8	399.1
3.5		41.9	83.8	125.7	167.6	209.5	251.4	293.4	335.3	377.2	419.1	461.0	502.9
4.0		51.2	102.4	153.6	204.8	256.0	307.2	358.4	409.6	460.8	512.0	563.2	614.4
4.5		61.1	122.2	183.3	244.4	305.5	366.6	427.7	488.8	549.8	610.9	672.0	733.1
5.0		71.6	143.1	214.7	286.2	357.8	429.3	500.9	572.4	644.0	715.5	787.1	858.6

The temporary check dams most commonly used in gully-control work are made of woven wire, brush, loose rock, planks, or slabs. Satisfactory dams may be constructed, how-

ever, from other materials or from a combination of these materials. The type selected for use will depend generally on the materials available. *Woven wire, brush, loose rock,* and *slab dams* are illustrated in Graphs 7, 8, and 9 and Fig. 72.

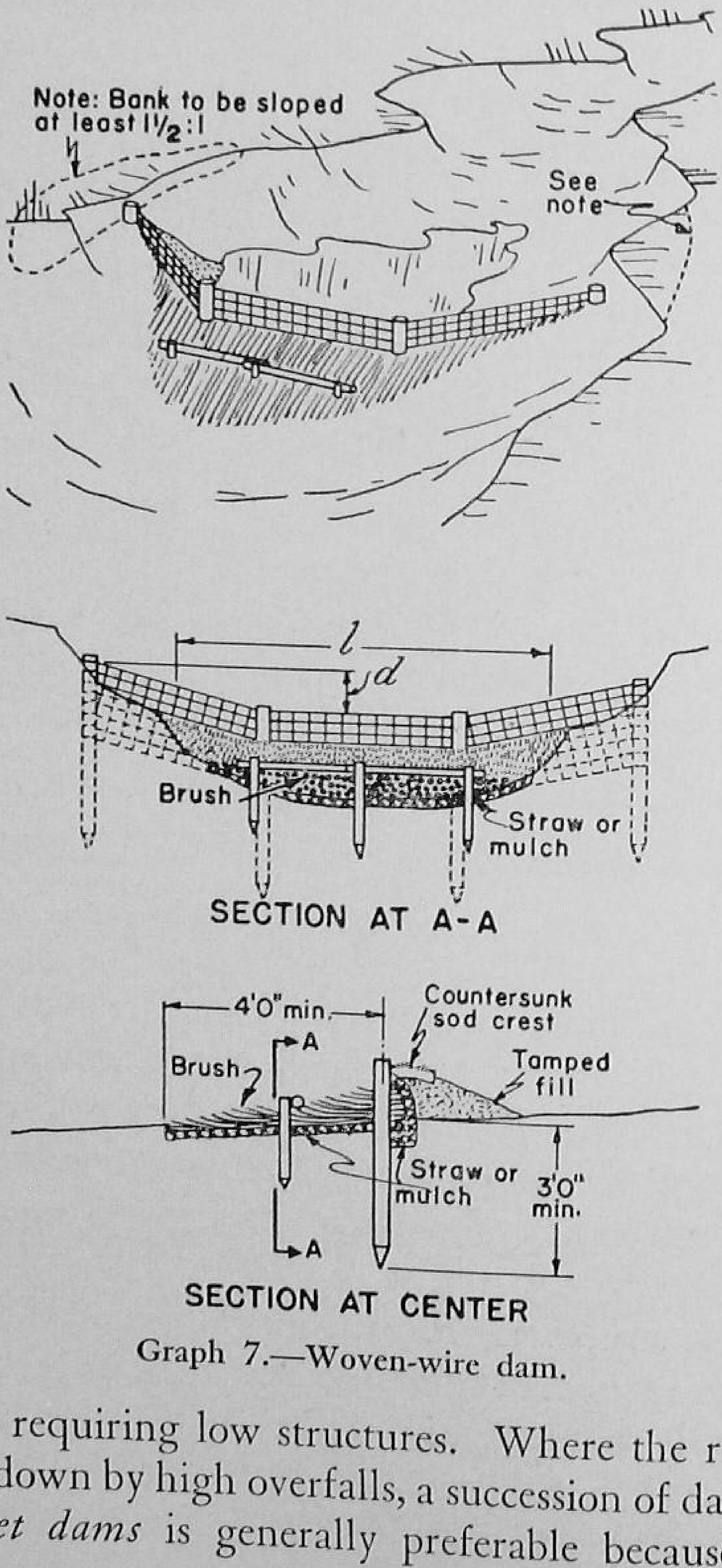
Fig. 72.—A slab dam in a small gully.

Where site conditions are favorable, another type of dam frequently used in gullies with small watersheds and moderate slopes is the *willow-post dam*. The posts or poles are cut from green willow trees and set in rows across the gully at intervals of about 1 foot. They take root and form a living check across the gully.

Permanent structures are used in gully-control work where temporary measures are either inadequate or impractical. They are frequently necessary in gullies with large contributing watersheds and in gullies that must be retained as permanent waterways. Any gully beginning to cut back into a large

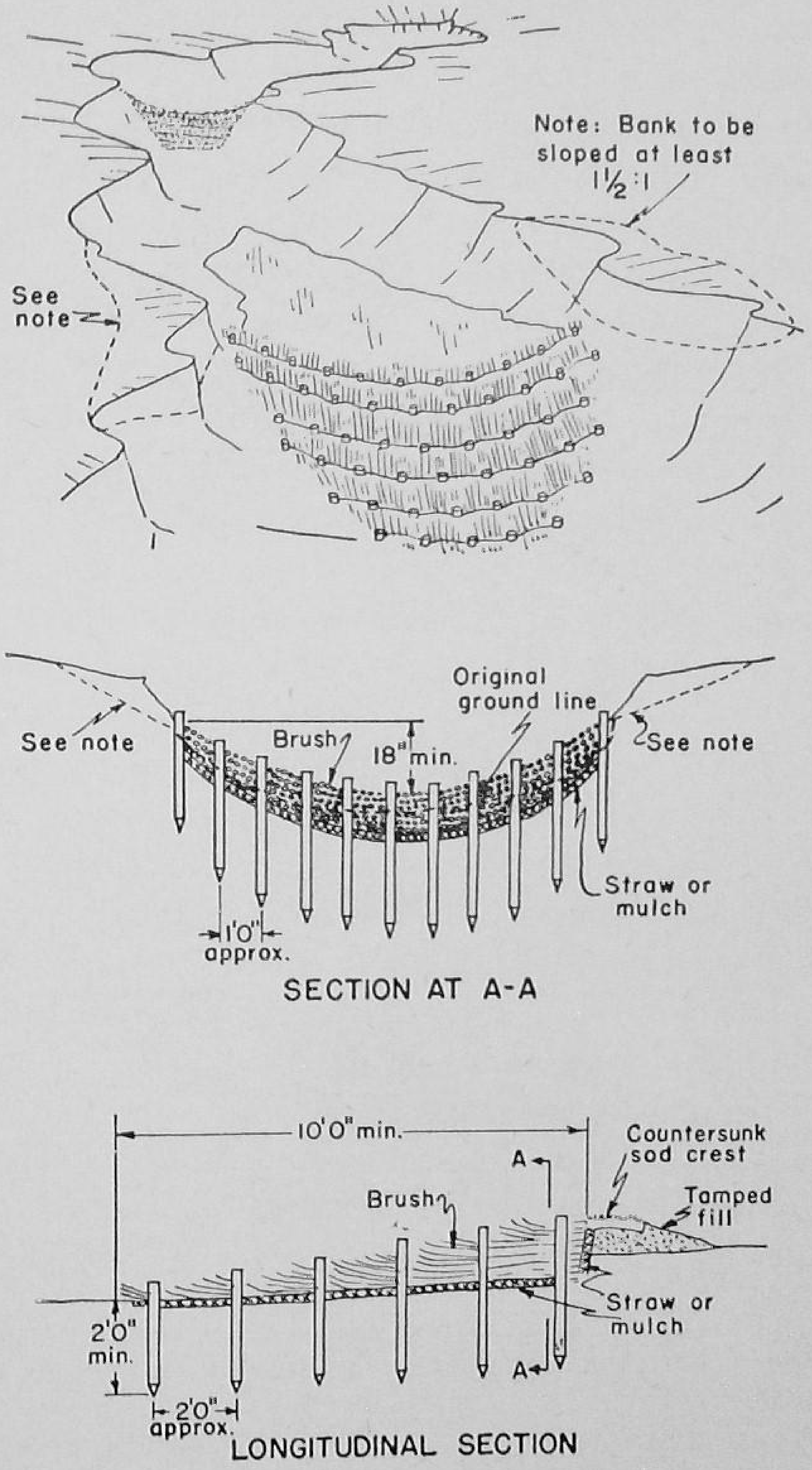
watershed usually will justify control by the use of permanent structures.

Weir-notch (gaps for water flow) *dams* usually are employed

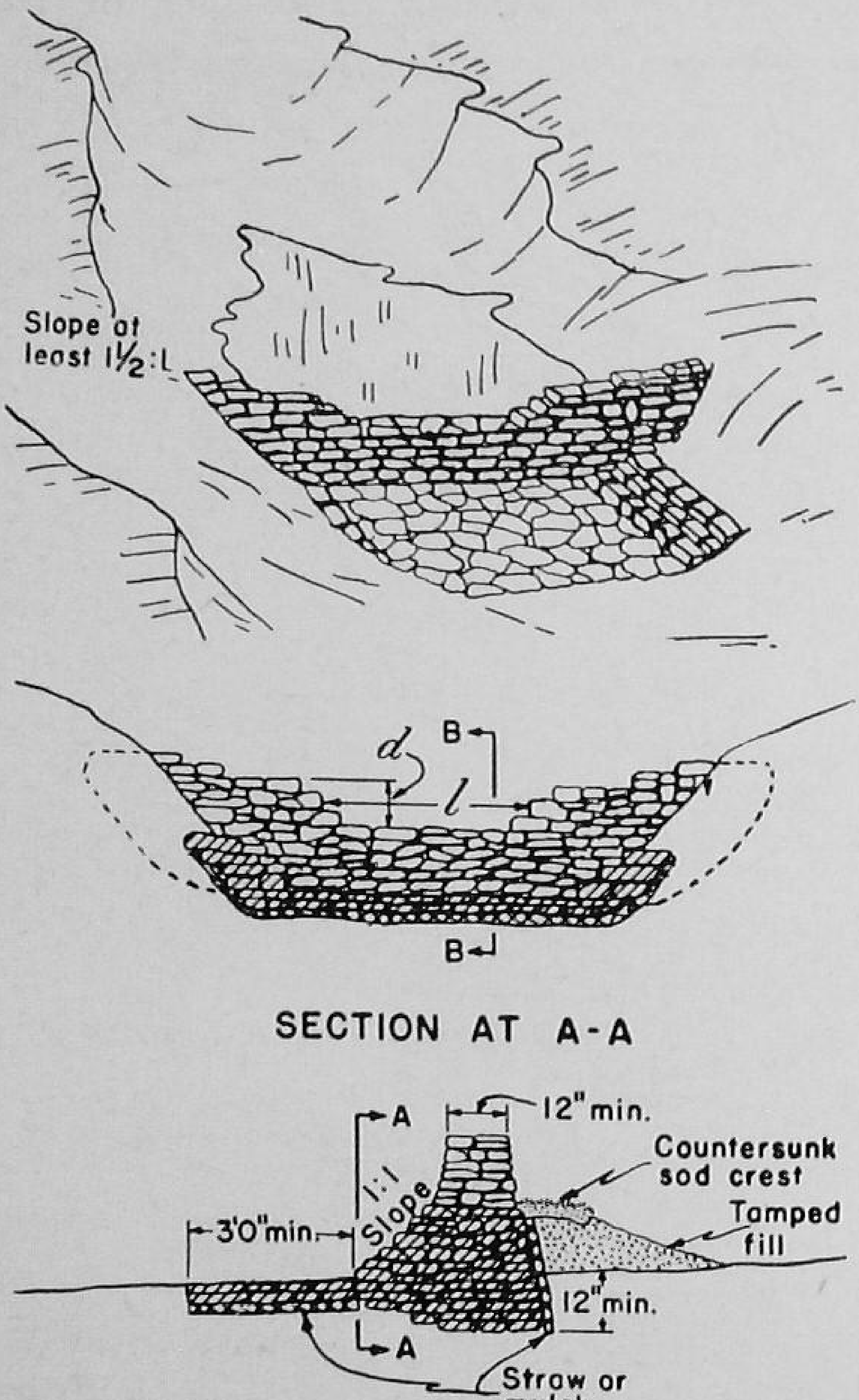


Graph 7.—Woven-wire dam.

in locations requiring low structures. Where the runoff must be brought down by high overfalls, a succession of dams, flumes, or *drop-inlet dams* is generally preferable because the rela-



Graph 8.—A type of brush dam in common use.



Graph 9.—Loose-rock dam. Where the rocks are small, it frequently is necessary to anchor them with woven wire stretched tightly over the structure.

tively high heads that would be required for weir-notch dams would necessitate heavy reinforced concrete construction. Ordinarily, neither masonry nor concrete notch dams should be used to control overfalls in excess of 6 to 8 feet.

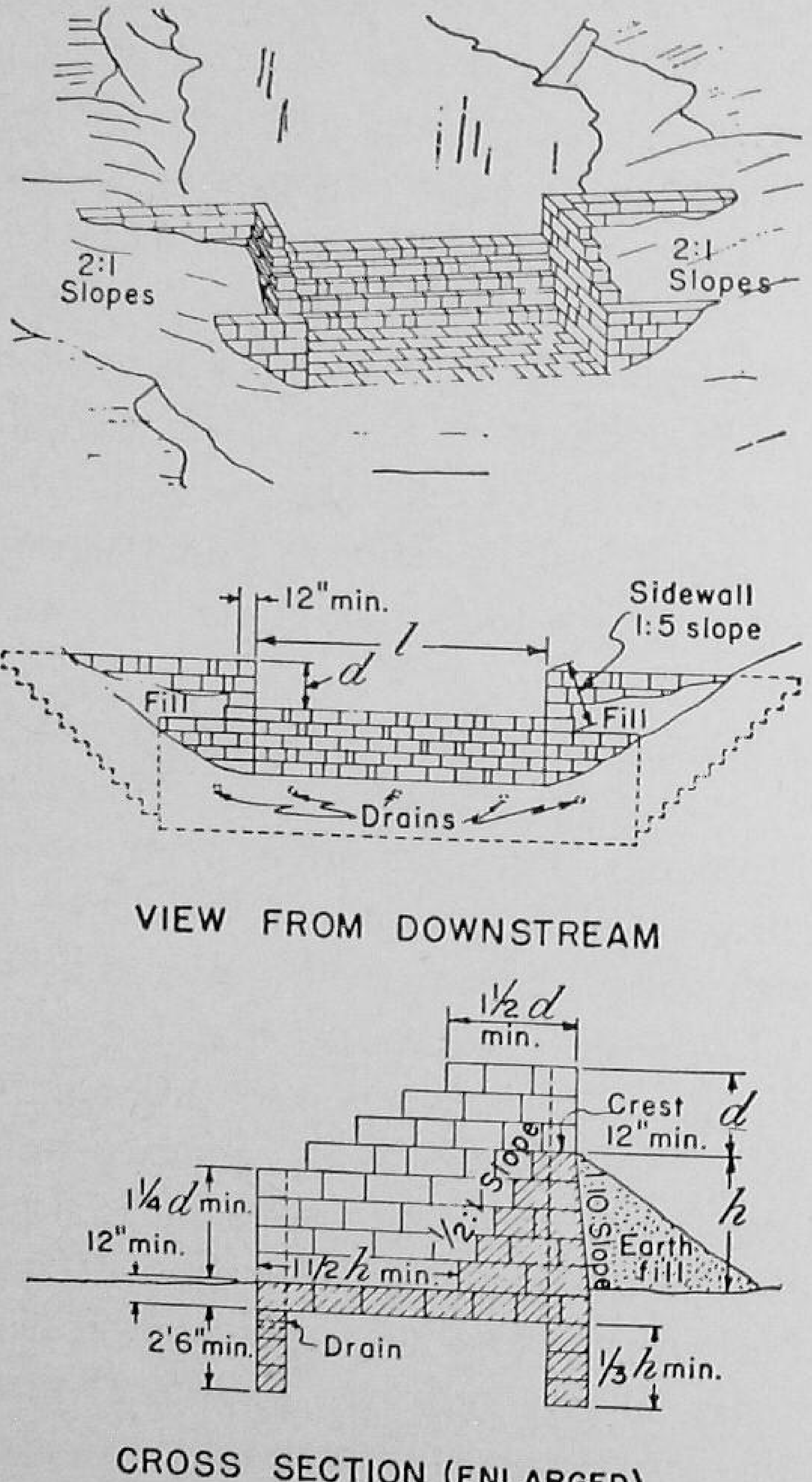
Since discharge quantities and velocities are relatively high, channel grades below or between permanent structures should rarely exceed 1 per cent unless the channel bed contains sufficient rock to prevent harmful scouring. The stability of a permanent gully-control structure depends on stabilized grades in the channel below. An excessive grade leads to the development of an overfall that gradually will undermine the structure. Such a grade can be reduced by changing the location of the structure or by constructing the spillway apron at a lower elevation.

Cutoffs to check seepage and washouts around or underneath structures are important. These should extend sufficiently far into the bottom and sides of the gully to provide adequate sealing. Generally, wet foundations should be avoided, especially for earth dams. Surface soil and organic matter should be removed from the dam site so that a good bond can be established between the structure and the impervious foundation material. Below the dam, an apron of sufficient length, width, and depth to prevent undermining is also necessary.

The smaller permanent dams (Graphs 10 and 11) should be designed to withstand the maximum runoff from individual storms that may be expected over a 10- to 15-year period; but because of the greater expenditures involved, the larger ones should be built to handle the runoff from the heaviest expected rain over a 25- to 50-year period. Table 9 may be used to determine spillway sizes for small permanent dams with rectangular-notch spillways.

Drop-inlet highway culverts are being used successfully to combat gully erosion along highways. Frequently, the bottom

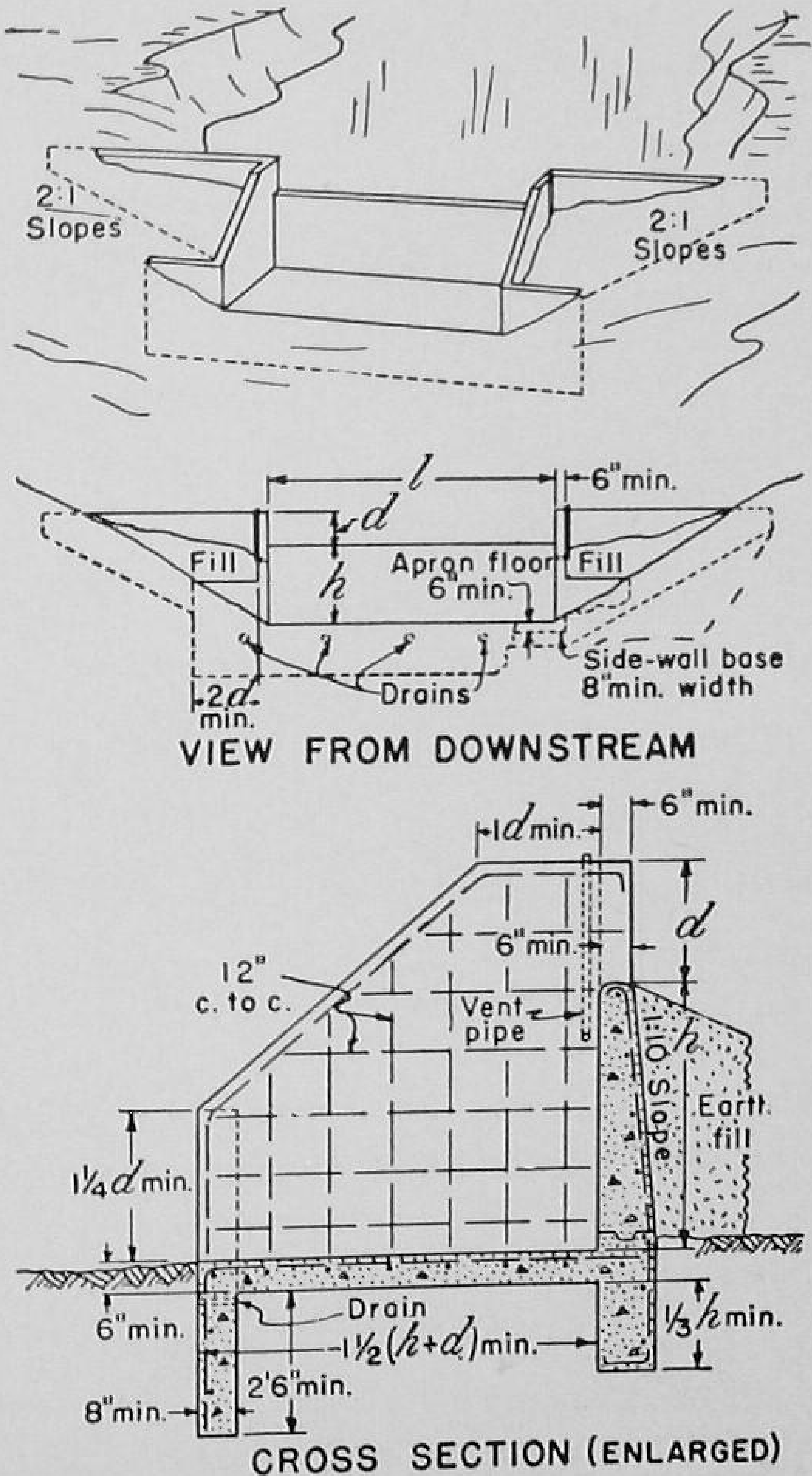
of highway culverts is below the bottom of the roadside ditches, so that water carried by the ditches must drop in order to pass



Graph 10.—Design for small rubble masonry dam where the height "h" does not exceed 5 to 6 feet.

through the culvert. Unless controlled, severe gullying often has its beginning at the critical point of the drop. The desired protection can be established by installation of a drop inlet

(Fig. 73) in the form of a drop box (inlet) at the entrance of the culvert.



Graph 11.—Design for small concrete dam where the height "h" does not exceed 5 feet.

The weir length *L* and the depth *D* required for the flow of various quantities of water over a notched dam are shown in Table 9. The required weir length for the drop inlet is ap-

proximately one-fourth greater. It is often necessary to protect the discharge end of the drop inlet conduit to prevent

Fig. 73.—Entrance (riser or well) to drop inlet for passing runoff through a highway culvert.

gullying. This can be done by using a boxlike structure for diminishing the cutting effect of the water—known as a *stilling basin.*

Questions

1. How does an undercutting gully differ from a V-shaped gully?
2. Name the principal methods of gully control.
3. Give examples of control with structures.
4. What is the effect on rate of erosion when a gully head nears the crest of its watershed?
5. What is a filter strip?
6. What is waterfall gullying?

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CHAPTER 15

Control of Erosion on Stream Banks

PRESENTING:

Economic Aspects of Stream-bank Erosion
Causes and Types of Damage
Technical Feasibility of Stream-bank Control
Stream-bank Protection

Stream-bank erosion is occurring on a large scale in every part of the country, along small trout streams and farm brooks as well as along such great waterways as the Mississippi and Missouri.

Economic Aspects of Stream-bank Erosion. Stream-bank erosion is a problem of public concern because it destroys economic values. It ruins extensive areas for further productive or recreational use and contributes to the clogging of stream channels, thus adding to the hazard of floods. A considerable part of the silt deposited in some reservoirs comes from stream-banks. Bridges and other structures across or near stream channels are damaged by this form of erosion, and shifting channels caused by the erosion increase the cost of their maintenance.

Agricultural areas undercut or washed out by bank erosion usually consist of high-value alluvial land. While the bank is eroding on one side of a stream, however, land sometimes builds up on the opposite side. The comparative age of trees, measured from the shore inland, has shown in a number of instances that land destroyed on one side of a stream was re-

placed by cultivable soil on the opposite side within a few decades. Thus, it is indicated that approximately the same number of acres in some flood plains have been available for agricultural use many years; and unless sedimentation causes serious economic damage, the public concern is not so great.

Erosion of this type, however, is a matter of immediate importance to the individual farmer, for it means a decrease in the potential farm income. When rich bottomland is destroyed, a vital part of the farm's assets is lost. And, too, good washed-out land often either is not replaced at all or is replaced with worthless swamp, marsh, gravel bars, etc.

Causes and Types of Damage. Frost, water, and ice are the erosive forces that cut away stream banks. Scouring, gouging, undercutting and sloughing, and mud flows are the principal processes of bank deterioration. These are influenced by such conditions as soil character, presence or absence of a stable cover of trees or shrubs, size and character of floods, the velocity of the current, the land use on adjacent areas, stability of the river-bed material during floods, and climatic conditions.

Stream-bank erosion has become more severe and more widespread in recent years because of the more intensive use of alluvial plains and their enclosing uplands. In some instances, the process has been accelerated by neglect or unwise use on the spot.

Technical Feasibility of Stream-bank Control. Stream-bank protection is usually very costly, especially on large streams. For this reason, plans for such work, particularly in the case of structures, should be based on carefully prepared surveys and designs. This will require a knowledge of the physical conditions of both watershed and channel as well as the character of the stream flow. Final selection of the most adaptable type of structure for a particular section of stream bank will

require careful consideration of hydraulic principles governing location and design of the structure. Such work should not be attempted by persons lacking a good understanding of stream flow.

Fig. 74.—Where lower banks are kept soft by fluctuating water level, control frequently requires stone riprap below and vegetation above. Winooski River, Vermont. (Work by Soil Conservation Service.)

Stream-bank Protection. Two principal types of stream-bank protection have long been used in various parts of the world. One involves the *blanket* method of protection, and the other is known as the *jetty* method.

The cheapest type of blanket protection is an effective cover of vegetation. Along small streams, a good sod of grass often gives adequate control, except under conditions of severe gouging by ice. Probably the most effective type of vegetative covering under any condition is a stand of willow trees about

4 to 6 inches in diameter. Trees often must be fenced from grazing, as thin stands with bare ground between, such as often result from grazing, permit erosion to start. Once erosion has started, the trees are likely to lose their foothold and so induce severe bank erosion.

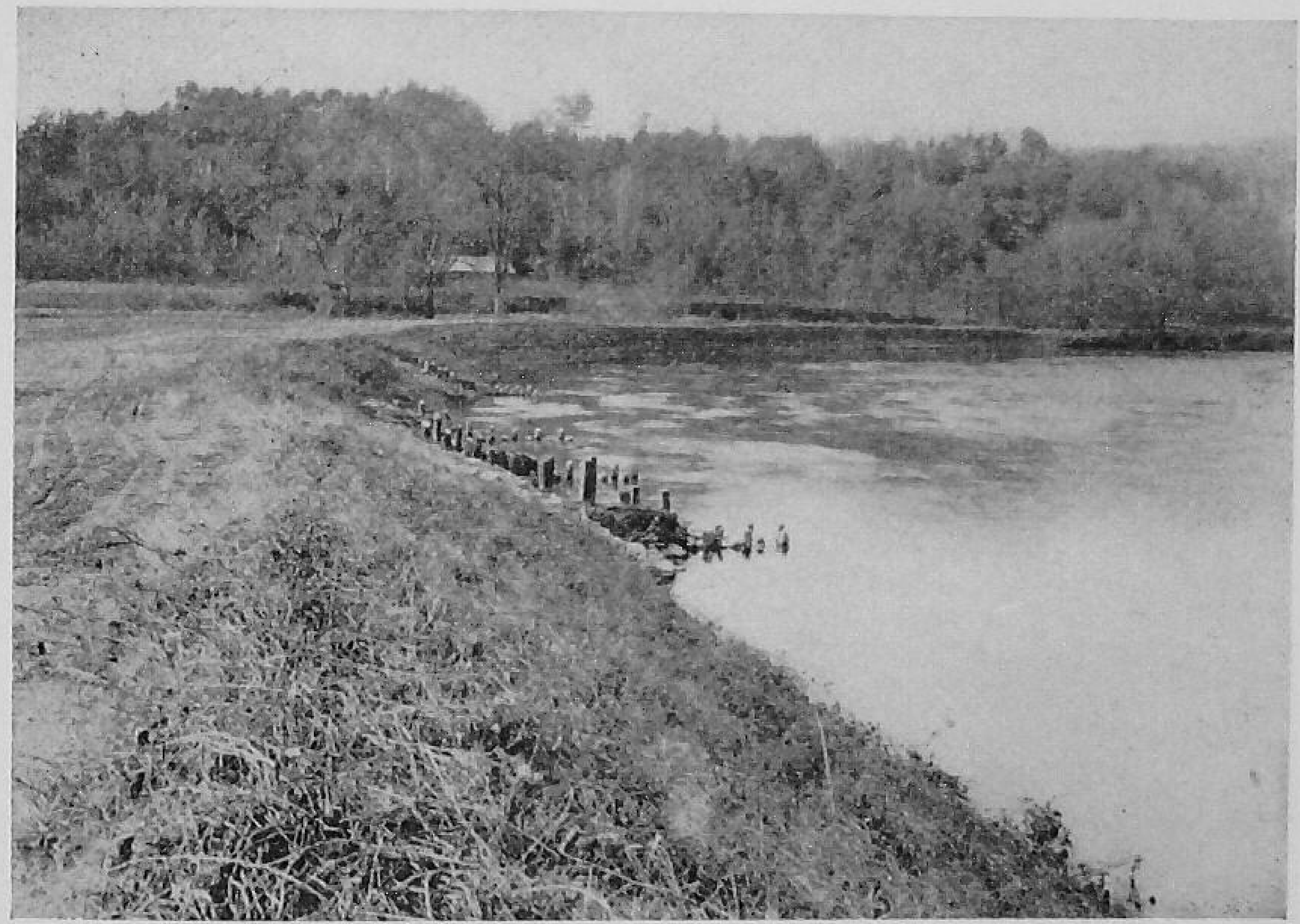


Fig. 75.—Bank treatment with brush matting and timber pile jetties. (Work by Soil Conservation Service.)

Belts of willow trees planted on the flood plain parallel to the banks are effective in retarding current velocities, thereby reducing the erosive force of water and floating ice. Where the lower part of a stream bank is under water every year long enough to prevent vegetative growth, it is often necessary to cover this more vulnerable section with stone to adequate depths below the water line (Fig. 74) or to provide effective jetty protection (Fig. 75). In deep water, the *timber-pile jetty* is usually more economical and effective. Where

current velocities are not too swift (less than 3 miles per hour), the toe of the slope sometimes can be protected by anchoring large trees in a continuous line parallel to the bank to break the velocity of the current and to cause silt deposition (Fig. 76).

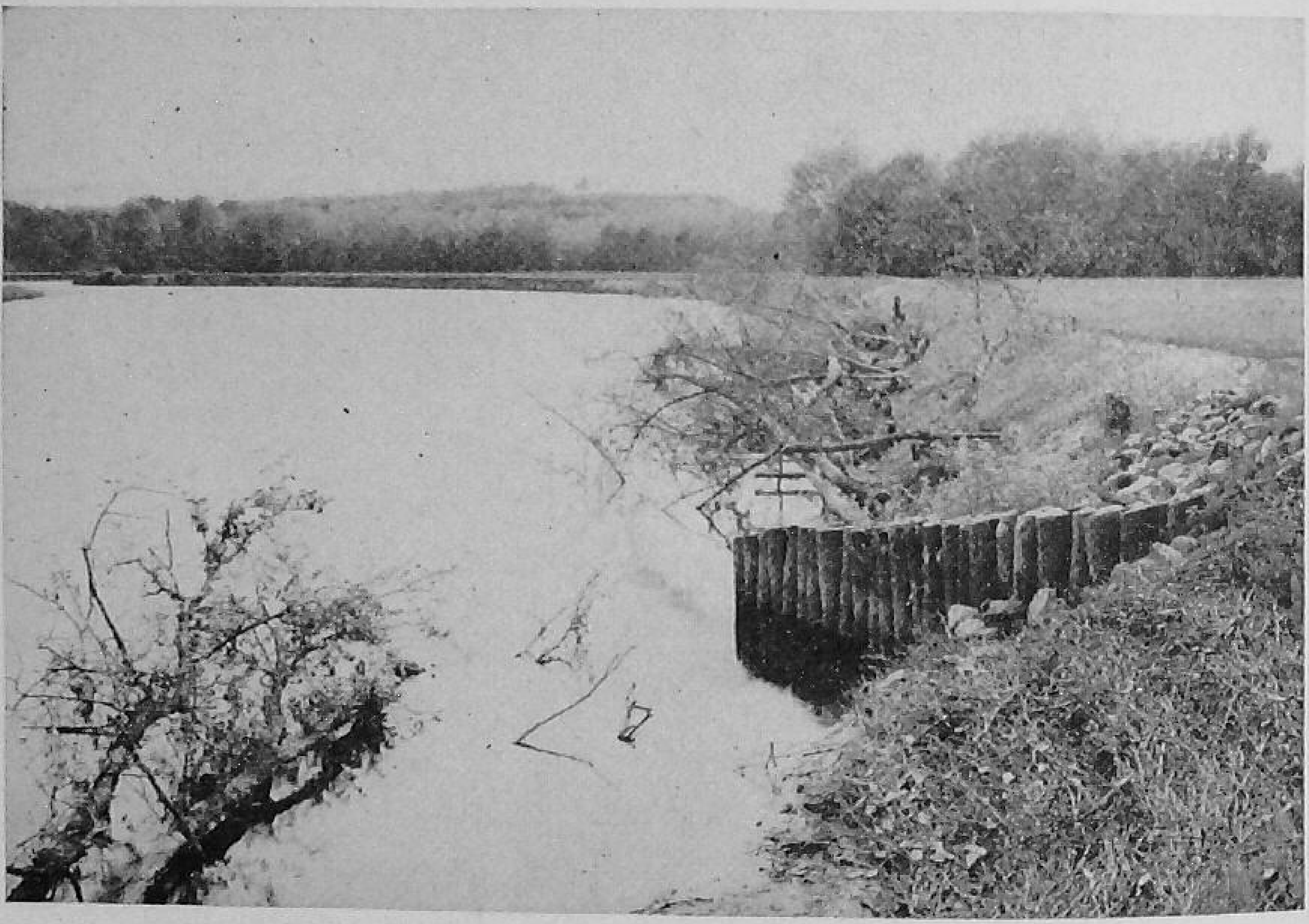
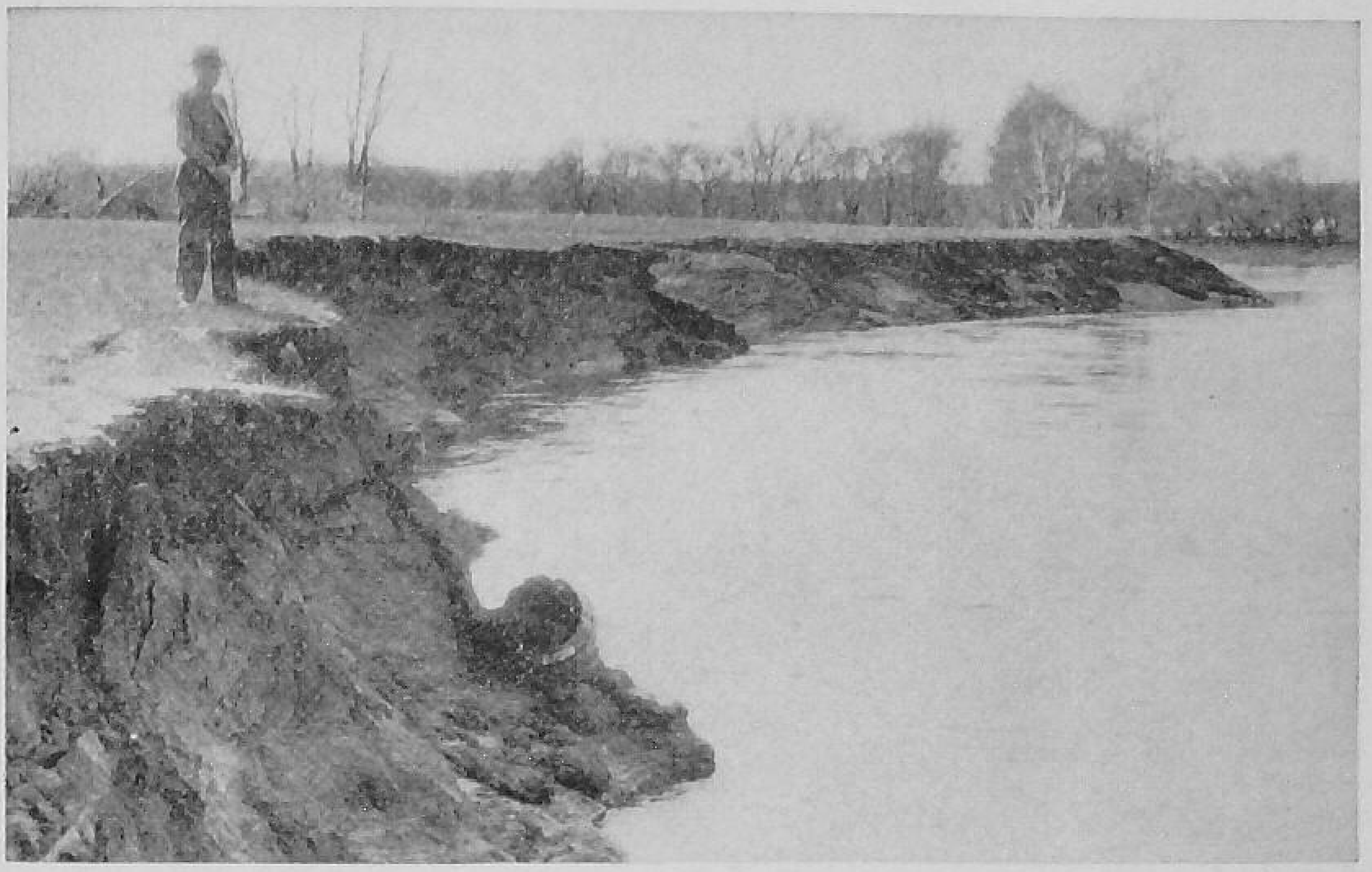


Fig. 76.—Caving controlled with trees anchored against bank after sloping. Lower Winooski River, Vermont. (Work by Soil Conservation Service.)

Where the banks are so bare that some temporary protection must be provided pending the establishment of a protective cover of trees, compact brush matting, preferably of willows (Fig. 77), generally has proved effective and economical, even under severe ice conditions. Ordinarily, the brush is anchored to stakes with wire; where it is laid parallel to the current, weighing with stone or concrete blocks is generally advisable. Where ice action is not a problem, the brush may be laid at right angles to the current as an inducement to deposition of silt.



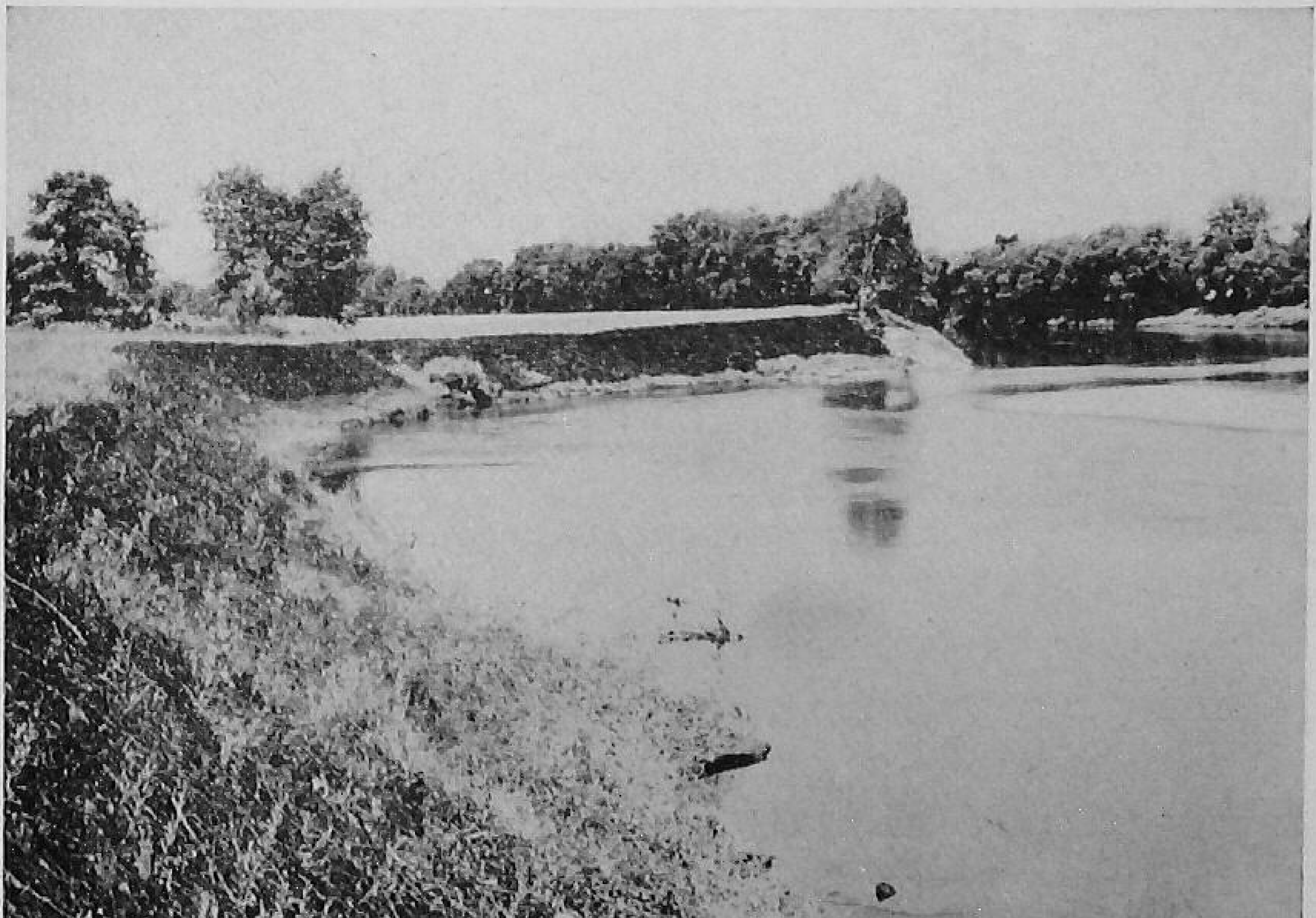


Fig. 77.—Above, destruction of productive bottomland by bank erosion; lower, same area controlled with brush matting. Winooski River, Vermont. (Work by Soil Conservation Service.)

At extra-vulnerable points, as sharp bends subjected to swift currents, control through revegetation is sometimes impossible to obtain. Under such conditions, it is necessary to riprap the banks with stone. Where erosion of highly valuable land

Fig. 78.—Control of bank erosion by riprapping, after sloping. (Work by Soil Conservation Service.)

must be stopped immediately, a blanket covering of stone or concrete is usually the only practicable procedure to follow. Blanket protection of any type requires some preliminary sloping of the bank (Fig. 78).

In such instances, the jetty type of control should be used. This can be used alone or in combination with blanket protection. The types of jetties to be used and the necessary spacing, distance and angle for extension into the stream will vary

with the size of the stream, channel gradient, maximum expected velocity, character of flood flow, ice conditions, and availability of construction materials. Effective jetties have been constructed of barriers of trees, timber, piles, stone, pipe and concrete tetrahedrons, automobile frames, and other materials. Timber piles have proved particularly successful, both as jetties and as a means of assisting in the control of especially vulnerable banks (Fig. 79). In some parts of the West where ice is not a serious problem and where large quantities of silt are transported, loose jetties of brush and piling have given adequate protection. *Permeable-type jetties* are generally the most successful, since they not only slow down the velocity sufficiently to cause silt deposition but help stop bank erosion. Impermeable jetties, functioning as dams, are often more expensive and more likely to induce scouring.

Very small streams generally can be protected with such simple and cheap measures as bank sloping and planting of willows. In the low-rainfall areas of the West, particularly in the Southwestern range country, numerous waterways that formerly were well stabilized and of diminutive size have been converted into deep gullies or broad "washes" as the result of overgrazing of watersheds. Increased volumes of runoff from such abused upland areas start erosion along the channels; soon a U-shaped gully is opened. This spreads by a process of bank undercutting until, in many instances, the entire alluvial plain is washed out. The only cure for this type of bank erosion is to rehabilitate the range and protect the wash or gully with plantings of trees, shrubs, or other adaptable vegetation.

The choice of bank-protection measures is an individual problem for each stream and must be based on careful study of existing and expected conditions. Ingenuity is often the

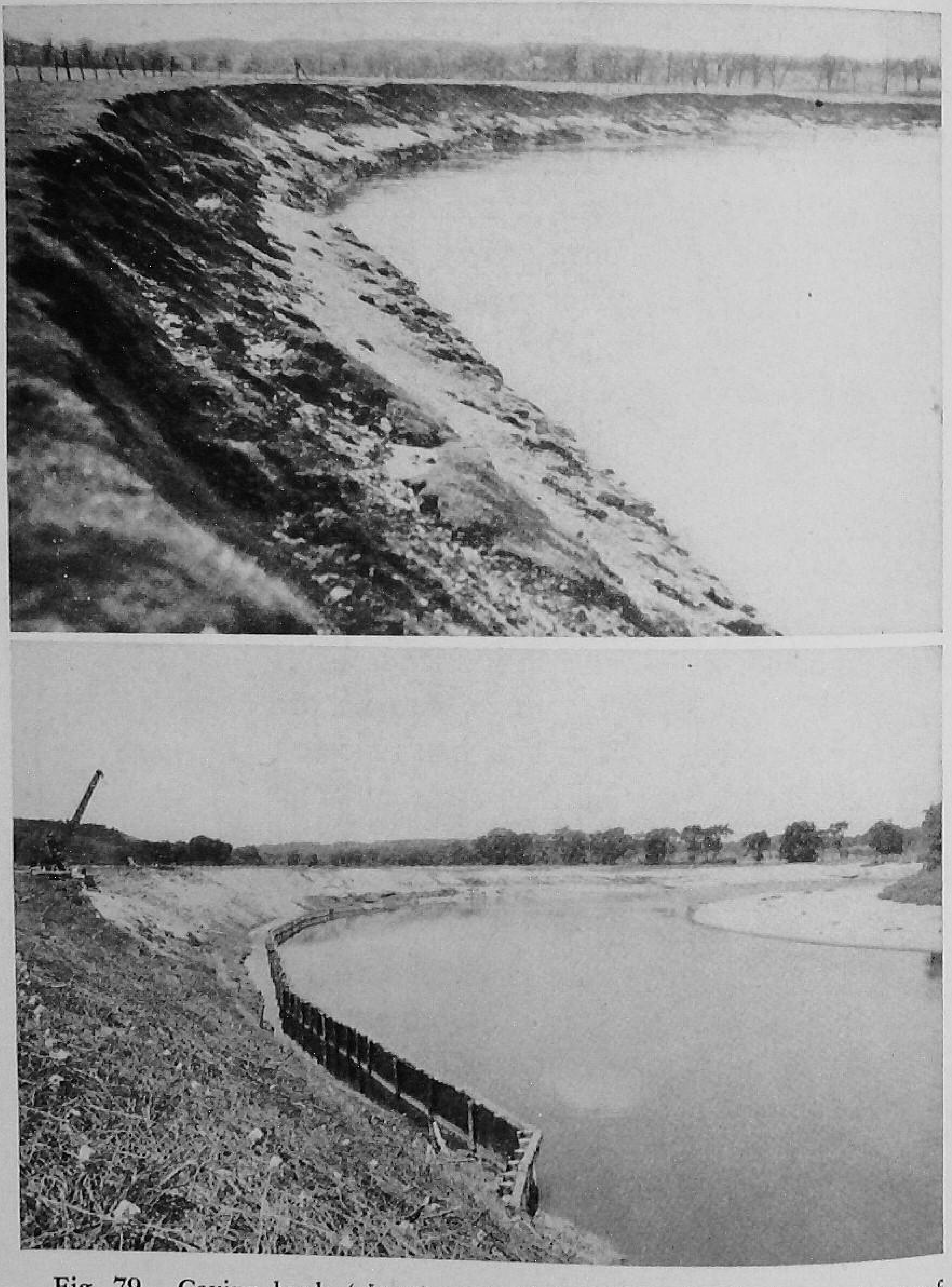


Fig. 79.—Caving bank (above) controlled (below) by sloping and use of piling and wired willow matting. (Work by Soil Conservation Service.)

keynote of the design and construction of stream-bank protection works.

Questions

1. What is the economic consequence of stream-bank erosion?
2. What is meant by blanket protection of stream banks?
3. Give examples of vegetative controls; control with jetties, with anchored trees.
4. What causes caving banks?
5. What are the most vulnerable parts of stream banks?
6. What special precautions are necessary in stream-bank control work?
7. How does stream-bank erosion sometimes balance the damage?
8. How does climate affect the problem?

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CHAPTER 16

Water Spreading

PRESENTING:

Adaptability of Land to Water Spreading
Principles of Water Spreading
Water-spreading Structures
Methods of Spreading Water

As a means of providing additional water needed for establishing or restoring a protective cover of vegetation in areas where rainfall deficiency ordinarily restricts the development of an adequate cover for erosion control, water spreading, or "flood irrigation," can be used effectively on many low-lying, flat areas.

Water spreading has been limited largely to the semiarid sections of the West. It has been used principally in connection with the rehabilitation of the range and for crop production on areas receiving too little rain for growing the ordinary crops. Soil on which water is to be spread should be fertile, of gentle slope, and capable of absorbing and making productive use of the extra water. This method of supplementing rainfall on selected areas should be used only under conditions of proper grazing control and the use of other conservation practices, if needed.

Adaptability of Land to Water Spreading. Where the soil is generally rich and of favorable permeability and the slopes gentle and smooth, the annual amount of rainfall may provide

a general guide in determining the adaptability of land to water spreading. Areas having an annual rainfall of less than 8 inches or a growing-season rainfall of less than 4 to 5 inches may not produce sufficient runoff to justify the installation of water-spreading systems. Where the annual rainfall ranges from 8 to 14 inches, the most productive possibilities of water spreading may be for the improvement of range forage or the production of supplemental feed; but under especially favorable conditions of soil and topography, dry-land crops can be grown successfully. With a rainfall of 14 to 25 inches, the opportunity for successful production of supplemental feed and cultivated crops is generally much more encouraging.

Principles of Water Spreading. Measures designed for water spreading vary with the purpose for which they are to be used. Certain basic principles govern the design of any well-planned water-distribution system. They involve consideration of minimum, normal, and maximum flows, character of the silt load, diversion sites, size of spreading area, texture and fertility of soil, topography, disposal of silt and waste water, and construction and maintenance of diversion and spreading structures.

When water first comes in contact with most soils, initial absorption takes place quickly. Thus, by the time the water has reached the lower end of a flooded area, the upper end will have absorbed both the initial intake and some continued intake during the full period of flooding. For this reason, the amount of water diverted over a given area should be regulated, as nearly as practicable, at the head of the area, so as not to exceed the amount necessary to cover the tract. If it is impracticable to avoid the use of extra water, provision should be made for safe handling of the waste at the lower end of the tract to be flooded. It is advisable to spread the water as evenly as possible over the area and to control the velocity so

that maximum absorption may be obtained with a minimum of soil movement. Distribution is accomplished primarily by proper spacing of contour furrows; by subsoiling; by advantageous placement of brush, rock, or woven-wire *percolators* (porous structures for retarding and spreading water); and by masonry, concrete, or other type of spreader. Where large quantities of silt are involved, it is also desirable to give consideration to its even distribution, as nearly as may be practicable. This may require some adjustment in the rate of flow by means of properly located spreader structures or the use of strategically located grass filters to take out part of the silt load so as not to concentrate too much coarse sediment near the point of diversion.

Water-spreading Structures. As yet, standard specifications have not been developed for many water-spreading structures. Methods of construction and location and type of structure are largely controlled by local conditions and experience of those charged with installation. The spreading system must, of course, be fitted to the expected amount of runoff, the size and surface configuration of the spreading area, and the soil for most efficient use of the water. Much depends on the experience and skill of the man who selects the site and installs the system.

Methods of Spreading Water. Where runoff concentrated in a broad, shallow gully or wash is to be spread over adjacent areas, a series of small graded furrows, ditches, or ridges (small embankments or dikes) provide one of the simplest means for diversion and spreading. Frequently, a combination of graded and level furrows or ridges will give the most effective results. Direct diversion is accomplished by systematically locating the furrows or small dikes so that each turns out a small quantity of floodwater, usually not more than 1 or 2 second-feet, from the channel or flow way and conveys it over the spreading area.

In some instances, small check dams or diversions serve to turn the flows into the graded furrows or ditches or along wings of the diversion embankments; but frequently no such structure is necessary if the diversions can be satisfactorily extended across or well into the depression from which the water is to be diverted. Additional furrows or percolators are frequently constructed on the contour below the discharge end of the diversions in order to spread out the discharged water. With enough diversions of this type on both sides of the channel, large flood flows sometimes may be disposed of entirely, so that water that formerly was running to waste and cutting away rich soil is turned to economic use and the erosion stopped.

On uniform slopes, contour furrows and ridges generally can be used advantageously with all types of spreading systems to minimize concentration of water in natural depressions and to increase absorption. Close spacing of furrows and ridges is advisable immediately above gullies, critical slopes, and irrigation canals. Furrows for retaining, rather than conveying, water (Fig. 80) usually are turned upslope as gullies or natural depressions are approached in order to close the ends. Where soil conditions are unfavorable to the use of furrows, subsoiling is practiced or brush, rock, or low woven-wire percolators are used, according to local conditions and availability of materials. Subsoiling on the contour usually results in increased absorption. Contour percolators constructed of brush or wire serve to slow up and spread the runoff. Silt usually is deposited immediately above such obstructions, and this, together with the additional moisture, favors the establishment of vegetation, either naturally or artificially. Thinning of dense stands of sagebrush, combined with the use of the brush to build contour percolators, is giving excellent results.

In many of the broad valley-fill areas (valleys filled with water-transported material) used for grazing, the procedures employed for gully control and water spreading are much the same. A combination earth-fill dam and broad-base earth dike

Fig. 80.—Runoff intercepted and spread by contour furrows and ridges. Dallas County, Texas. (Work by Soil Conservation Service.)

is generally used wherever practicable to turn all the water out of active gullies (Fig. 81). In some instances, the water is diverted with earth dikes before it reaches the gully. By means of carefully constructed openings in the dikes (weirs or *weeps*), part of the flow is released at strategic points along the structure and the remainder is discharged at the end of the dike. Where necessary, the water is spread still farther by furrows, ridges, or percolators strategically located below the discharge points. Where the gullies have long been established, waterways are restricted to locations where water rights

are not involved and where the spreading areas are of sufficient size and permeability to absorb all the diverted water. Locations for diversions should be selected where deposition of silt is likely to be least troublesome (Fig. 82).

Fig. 81.—Earth dike used for diverting runoff from an active gully head and conveying it to a spreading area for flood irrigation. New Mexico.

Where local conditions prevent complete diversion, partial diversions have been made to good advantage. Partial diversion from large gullies may necessitate the construction of a combination type of overflow diversion dam for by-passing minimum or normal flows and for controlled diversion of flood flows (Fig. 83). Since masonry or rock structures may be required for this purpose, the cost sometimes prevents their use. In a number of instances, however, results have justified the expense.

Excellent results have been obtained with two methods of water spreading in west Texas: one by a *sirup-pan* system of

terracing or diking and the other by *rationing* the diverted water into a system of closed-end level terraces. Frequently, a combination of the two methods is used on the same field.

The sirup-pan system is so designated because the water is

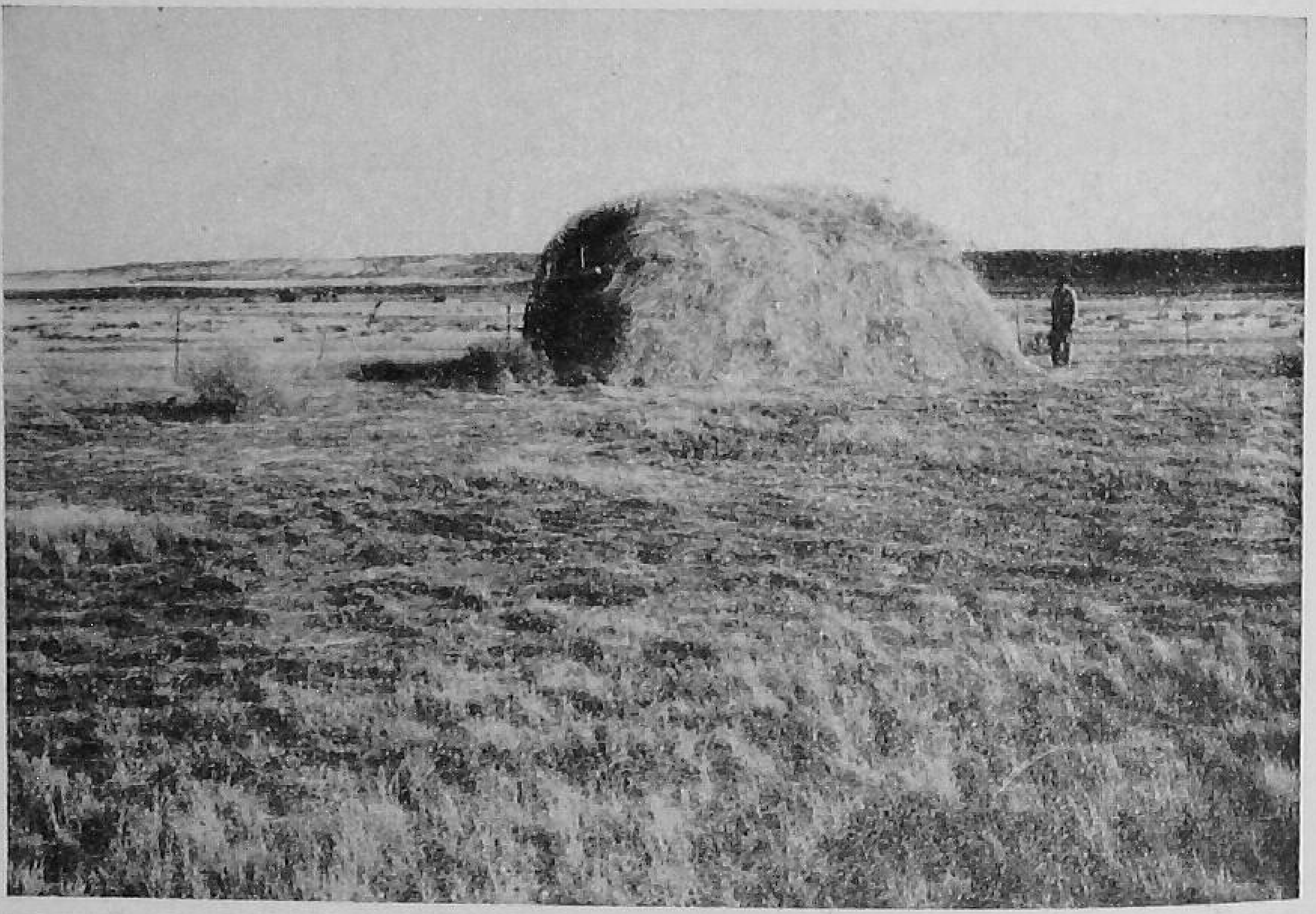

Fig. 82.—Hay produced near Mexican Springs, New Mexico, following flood irrigation of the area with water diverted from an expanding arroyo. Previously, this water ran to waste, carrying large quanties of silt into the San Juan River, thence into Lake Mead. (Work by Soil Conservation Service.)

made to flow back and forth across the field in the same manner as cane juice is processed in open sirup pans (Fig. 84). An upper terrace, collecting runoff from a drainage way or adjacent swale, carries it across the field to the opposite end of the terrace where the unabsorbed water is discharged so as to be intercepted and turned back across the field by the next terrace below. The water is thus directed back and forth across the field until all of it is absorbed or any excess is dis-

charged into a stabilized outlet at the lower side of the field.

Under the rationing system, each terrace receives a controlled amount of flood runoff from either a natural or an

Fig. 83.—A combination diversion and spreading system for rehabilitation of range on rich valley land, New Mexico. The structure in the water channel diverts normal runoff and by-passes surplus runoff during peak flows. A system of loose-rock percolators, located on the contour, spreads the diverted water over the adjacent land where it is absorbed. (Work by Soil Conservation Service.)

artificial drainage way. The purpose is to distribute the water between the terraces in amounts that will be absorbed by each of the interterrace areas. Various methods are used to regulate the amount of water delivered to each terrace interval. Merely regulating the inlet elevations is sufficient in some instances, whereas others require weirs with automatic or hand-operated gates.

The rate at which water may be added safely to an area depends on the infiltration capacity of the soil and the carrying capacity of the terraces. The soil should be capable of absorbing all the water applied within at least 48 hours; otherwise,

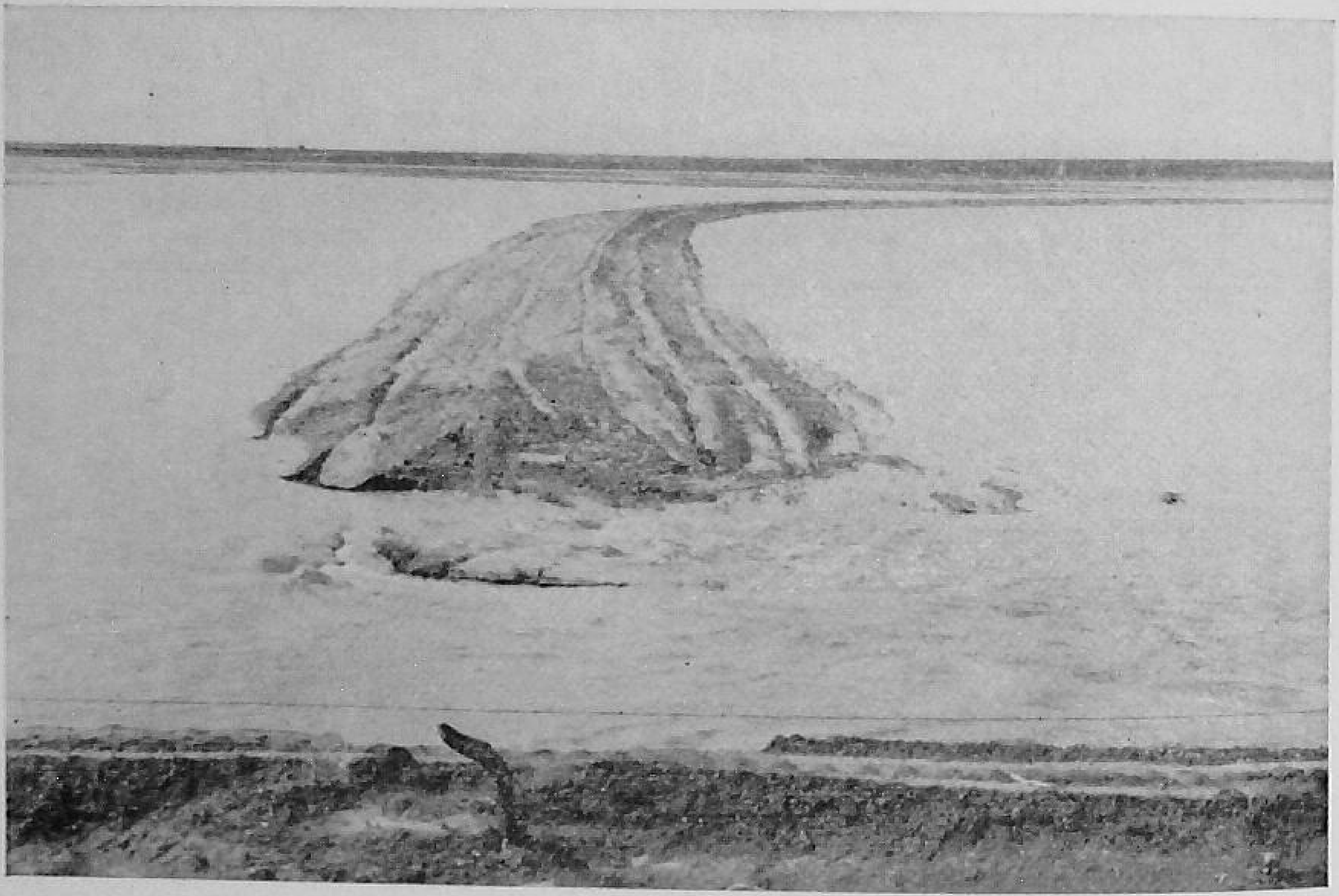

Fig. 84.—Water flowing round the end of one of the terraces in a sirup-pan system used for spreading runoff over a 160-acre Texas field.

crops are likely to be injured. On the Texas project referred to, the impounding systems providing surface-irrigation water for relatively large interterrace areas have a capacity of approximately 2.3 second-feet per acre.

The net returns from water spreading are sometimes so modest that improper construction or misapplication of either type or size of system may easily render the whole enterprise unprofitable.

Questions

1. What conditions govern the utility of water spreading?
2. What is the diversion method of water spreading?
3. What are contour percolators?
4. What is the sirup-pan system?
5. How does silt affect water spreading?
6. Why should provision be made for rapid absorption of water?
7. What time factor is important in water spreading?

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CHAPTER 17

Wildlife and Soil Conservation

PRESENTING:

Cover and Feed for Wildlife
Relation of Wildlife Management to Soil Conservation
Wildlife Practices in Soil Conservation
Modification of Practices to Meet Wildlife Needs

Soil conservation and wildlife conservation both depend fundamentally on the reestablishment and maintenance of protective stands of vegetation. Each, therefore, may make important contributions to the other.

The term *wildlife,* as used here, is restricted to undomesticated animals—mammals, birds, fish. The basic essentials of existence for such animals are cover, food, and water, usually of relative importance to land animals in the order stated.

Cover and Feed for Wildlife. With few exceptions, all wildlife must have cover of some sort: cover in which to conceal its home, cover into which it may dart when attacked by an enemy, cover in which to rest or sleep or in which it may find protection from the elements. Some animals require several kinds of cover, either at the same season or at different seasons of the year; others are less exacting. But all are alike in that, when they do need cover, it must be in such proximity to their food supplies that they will not be unduly exposed when foraging.

Without exception, all wildlife must have adequate food at all seasons in order to survive. Summer and fall are usually sea-

sons of plenty; but unless the supply continues to be available during the critical periods of winter and early spring, the resident wildlife population is doomed. To be available, food not only must be physically accessible (not covered by deep snow, for example) but must lie within safe foraging distance from habitable cover. Some animal species have different food requirements at different seasons, and the various items of diet must be available when needed. For example, many birds, which when adult live almost wholly on seeds, feed their nestlings on insects and soft fruits. Such birds, though not ordinarily thought of as insectivorous species, serve an important function in helping to hold insect populations in balance. The bobwhite is one of these.

Although free water is not essential to some quail, rabbits, and rodents, it is sometimes the limiting factor in the habitability of areas otherwise favorable for wildlife. Like food, water must be in such relation to cover that animals seeking a drink or bath will not fall too easy prey to their enemies.

Another wildlife fundamental is that animals generally are found in greatest numbers, both species and individuals, along the line of junction between diverse types of vegetation—for example, the margin between fields and woods. This fact has given rise to the expression that wildlife is a phenomenon of edge. In the encouragement of wildlife, therefore, efforts would be directed to the improvement of *edge* effect—the borders of woodland, field, and pasture. Maintenance of woodlands of mixed species of all age classes is also highly desirable for wildlife. Such a woodland (Fig. 85) represents, incidentally, one of the highest known types of soil protection. Contrast this with the wood lot shown in Fig. 86 where the trees are of about even age and there is no undergrowth because of grazing. The one will support a normal wildlife popula-

Fig. 85.—Unburned, ungrazed woodland of mixed species and age classes, with abundant undergrowth, provides maximum protection for the soil and excellent habitats for wildlife. Illinois.

Fig. 86.—A grazed woodlot of even-aged trees offers little soil protection, steadily declines in timber production, and harbors a minimum of wildlife. Pennsylvania.

tion, including ruffed grouse; the other, nothing save a few small tree birds and perhaps a family of squirrels.

Although these fundamentals pertain especially to land forms of animal life, they apply with but slight modification to fish as well. Fish, too, must have cover and food, and, of course, water is all important. Protection from enemies (cover) is as essential to fish as to land animals. Moreover, the quality of the water itself is highly important to fish. The best game fish can live only in clear, cool water practically free of silt or other pollutants. For fish, silt is the most deadly of erosion products; it buries their eggs, clogs the gills of their young, and, by shutting out light, destroys aquatic vegetation and the plankton on which they ultimately depend for food. Fish inevitably disappear from a stream well before the deposition of debris obliterates the channel, as shown in Fig. 87. In Fig. 88 may be seen all the elements of a satisfactory aquatic habitat: clean water, plenty of both marsh and aquatic vegetation to supply ample cover and some food, and banks well shaded and protected against erosion by a heavy growth of shrubbery.

Relation of Wildlife Management to Soil Conservation. The close relation of wildlife management to soil conservation is further attested by the fact that vegetation in both instances must be depended on to a very large degree to surmount the difficulties. The land has been laid bare through the necessity of producing crops to support an increasing human population. The reestablishment of vegetation on critically eroding bare areas is, therefore, not a simple matter of planting; it involves the whole question of using the land properly.

It follows that soil conservation involves the revision of the farm layout and its cropping system so as to achieve adequate protection for all land needing it while permitting maximum crop use of all safely tillable areas in order to insure profitable operation of the farm.

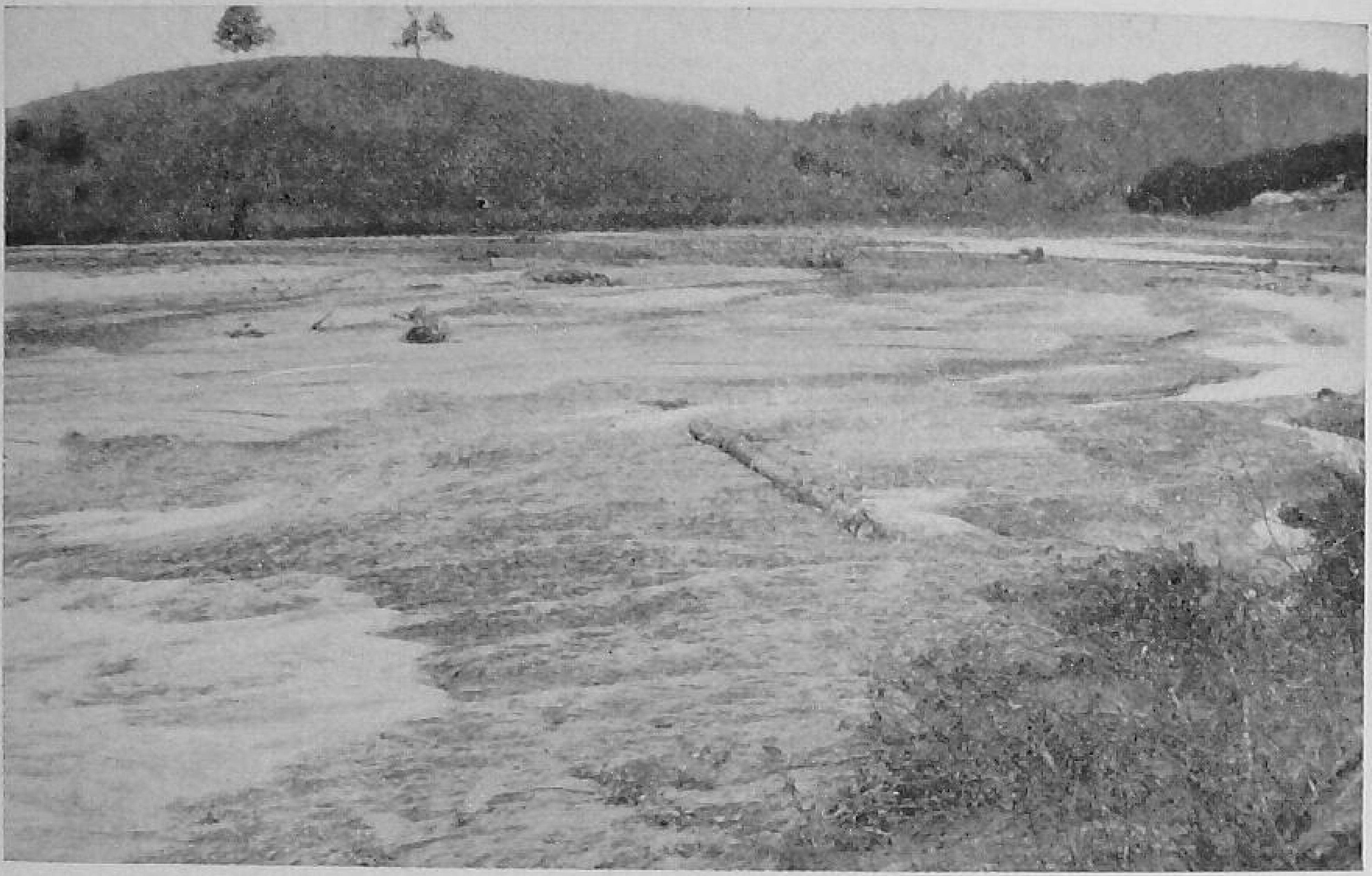

Fig. 87.—All that is left of a once lovely, clear-water Georgia stream utterly spoiled by erosion debris from unwisely cultivated hillsides. Fish have long since disappeared from the soil-muddied water. The flood hazard grows steadily worse.

Fig. 88.—Proper treatment of watersheds and protection of stream banks are imperative to safeguard aquatic habitats. Contrast this luxuriantly vegetated Wyoming stream of clear, cool water—alive with fish—with that in Fig. 87. (Work by Soil Conservation Service.)

Animal conservation involves the same problem of attaining its ends without upsetting the farm business. But just as it is possible to farm the land and protect it too, so it is feasible to farm in a way that will conserve wildlife and the land. Wildlife is a crop that may be produced over and above other farm crops occupying the same land. It can and should be a valuable by-product of nearly every well-managed farm plant.

Although wildlife needs adequate territory—it cannot be crowded—by proper distribution of suitable habitat areas the entire farm can be made to serve its purpose. By dedicating specific areas here and there to wildlife, the whole farm may be made available to this animal resource without sacrificing any appreciable amount of land.

The selection and treatment of these special areas bring about a particularly close tie-up between wildlife management and soil conservation. On numerous farms, there are areas that may not be safely plowed or that have so far deteriorated that crop production on them is no longer profitable. They present a high erosion hazard or an active erosion problem and cannot be ignored, although advanced erosion frequently renders control difficult. Such lands are "galled" spots (topsoil washed off), eroding sinkholes, gullies, eroding field and woodland borders, and cutting stream banks. Ordinarily, these places will not support economic types of vegetation; but when planted to certain forms of vegetation beneficial to wildlife, they often serve as just the areas needed to effect the desired variety of conditions favorable to wildlife. Thus, wildlife management steps advantageously into an important breach in the soil conservation program.

Wildlife management also makes a definite contribution to water conservation. Water does not long remain in good condition in unprotected reservoirs, farm ponds, and stock "tanks." Fence them against trampling and contaminating livestock;

and protect the shores with marsh plants against eroding waves. Not only will these precautions improve the quality of the water, but the reservoir will last longer and will become a veritable haven for animal life. This has been demonstrated throughout the country, especially in the Great Plains from Pierre to the Texas Panhandle.

In the relation between wildlife management and soil and water conservation, the contributions are not at all in one direction; the relation is reciprocal. Besides the elementary fact that without soil there would be no wildlife, nearly all soil conservation operations contribute something to the conservation of animal life. Strip cropping multiplies the amount of edge manyfold. Every measure that holds any soil in place keeps just that much from washing down to pollute streams and fill reservoirs. When the combined measures make it possible for streams again to run clear, fish may be restored to them. Before that time, there can be no fish management.

Wildlife Practices in Soil Conservation. In the vegetative protection of gullies, galled spots, sinkholes, abandoned roadways, eroding field borders, and rough places about the farm as well as eroding stream banks and pond and lake shores, wildlife plantings generally offer the best solution to the erosion problem. This is true because (1) the plants adapted to wildlife needs generally are those most likely to succeed under the local conditions and (2) the areas usually are too small or too inconveniently located for profitable yields of tilled crops, livestock, or wood products. Incidentally, relocating field fences on the contour and protecting them with plantings of woody vegetation is good erosion control practice and one of the best possible means of making all parts of the farm available to wild animals.

The type of treatment given these areas is determined by the conditions. Sometimes, nothing more is required than

protection from fire, livestock, and man. Occasionally, the engineer's assistance is needed to divert water or check its velocity; usually more or less planting is necessary in order to hasten the healing process. Species for planting should be chosen on the basis of their (1) adaptation to the sites, (2) ability to control erosion, (3) value as wildlife food or cover, and (4) usefulness in supplementing existing food and cover. They may be trees, shrubs, vines, or grasses. Whether entirely new habitats are created by these plantings or old ones rehabilitated, the ideal sought is adequate food and cover at all seasons (Figs. 89 and 90).

Farm ponds, range-water developments, and water conservation reservoirs offer the biologist an especially fruitful field of endeavor. Wildlife returns are usually rapid, sometimes amazing. During migration periods, ducks stop to rest on even the smaller ponds as soon as any water collects in them, although they are useless to nesting birds until food and cover are developed. The general practice is to fence such areas (with provision, of course, for watering stock) and plant the banks to woody vegetation and the shore lines to marsh plants (Fig. 91). As soon as cover appears within the protected areas, most of them are populated by nesting ducks, pheasants, or other kinds of birds and often by muskrats and other mammals.

In the establishment of new vegetation or the maintenance of old, protection from fire and livestock is of prime importance. Education and fencing, therefore, rank with planting as wildlife conservation measures.

Modification of Practices to Meet Needs of Wildlife. Average farms include four broad classes of land: cropland, pasture, woodland, and idle land. The first two and often the third cannot, of course, be used just for wildlife, and frequently there is not much idle land on good farms. Opportunity

Fig. 89.—Above: a gullied area in an Ohio pasture, worthless for grazing and obviously barren of wildlife, fenced and newly planted to black locust. Below: same area as shown in upper picture after two years. Provides cover for many birds and rabbits where none previously could live, and reduces runoff entering flood streams. In a few more years, a supply of fence posts will be ready for harvest. (Work by Soil Conservation Service.)

Fig. 90.—Above: a cutting stream bank in Wisconsin, practically devoid of cover, that has been fenced out of pasture and protected by willow plantings and a wattle of willow poles. Below: same stream bank shown in upper picture 14 months later. The willows already afford protection against bank cutting and provide excellent wildlife cover as well as considerable cooling shade for the water. (Work by Soil Conservation Service.)

for improving conditions for animal life would be limited indeed if restricted to idle or waste areas. Fortunately, there is no such limitation; for by appropriate modification of cropping, engineering, and woodland practices, a great deal may

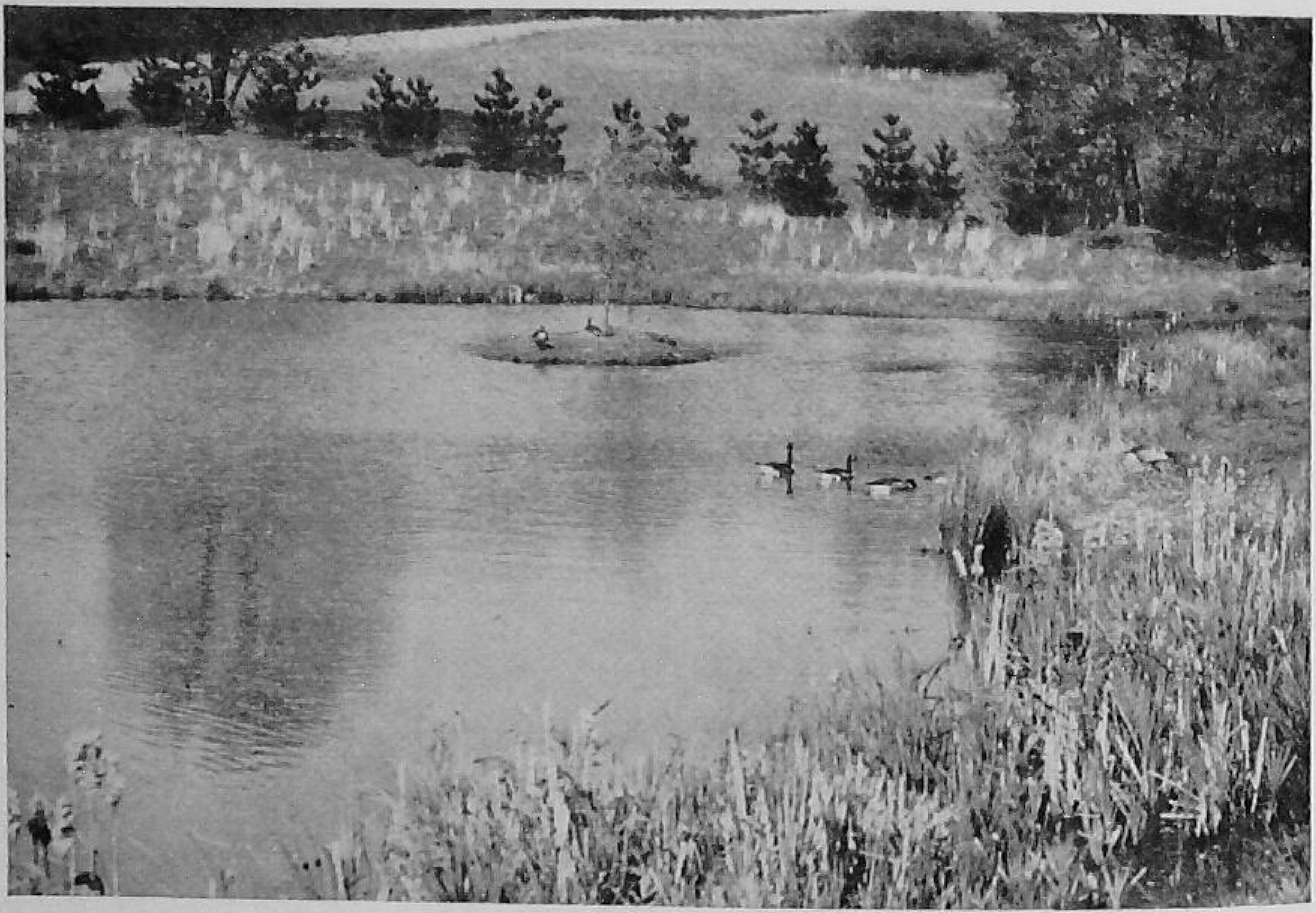

Fig. 91.—Vegetation about the margins of farm ponds prevents wave erosion and affords good habitats for water-loving wildlife. This Delaware farm pond is producing fish for food and sport; Canada geese nest on the little island. (Work by Soil Conservation Service.)

be accomplished without the least interference with the primary functions of these practices. The margins where fields and woods, fields and pastures, or woods and pastures adjoin are insignificant in area but, because of their important linear dimension, are of much importance to wildlife. Modifications of other technical practices, therefore, usually are designed to enhance the value of these borders.

Cropping practices may be turned to wildlife benefit in numerous ways. For example:

1. Strips of certain legumes, grasses, and other plants may be used to protect field borders, where erosion is often severe, especially adjacent to woodland. The encroachment of woodland on cultivated fields is an important farming problem. Insect depredations begin not at the center of fields or woods but at their edges. This measure, by attracting birds to such margins, contributes materially to the mutual protection of soil, vegetation, and animal life.

2. When appropriate plant species are used in protecting terrace outlet channels, field borders, and so on, these strips of vegetation provide food, cover, and breeding areas for certain birds and travel lanes for many forms of wildlife. In the Southern states, use of lespedezas on field borders—that is, where fields meet woodlands—serves those purposes admirably.

3. The maintenance of a limited number of trees and shrubs in pastures is of benefit to both wildlife and livestock.

4. Where deferred and rotation grazing are practiced, slight modification of dates for turning stock on an area may often permit successful nesting of certain birds.

5. In computing carrying capacities of the Western range, appropriate reservations may be made for wildlife.

6. In regions where large amounts of snow are removed by winter winds, fruit-bearing shrubs, strips of sunflowers, or grain sorghums often may be used in cultivated fields to hold snow in place. These strips provide cover and food for wildlife as well as fruits for home use. They also protect fields from wind erosion.

7. In fields of corn, legumes, and various grains, the outermost rows may be left standing over winter for wildlife food; or if all the crop must be harvested, the farmer may be urged to leave until last those portions adjacent to good wildlife cover.

Engineering practices similarly may yield benefits:

1. Structures such as terraces, terrace outlets, dams, spillways, and water spreaders often need the protection or supplemental support of vegetation for their maximum efficiency. Wherever possible, species furnishing food and cover for wildlife should be used.

2. Almost without exception, stock ponds should be protected by fencing. The shallower portions provide ideal habitats for many animals, especially waterfowl and shore birds, when properly planted. Aquatic and marsh vegetation may be used at inlets to desilt inflowing water and along shores to prevent wave action. Steep banks may be planted to herbs, shrubs, and trees to protect the banks from erosion. In more arid regions, woody plants of value to animal wildlife may be used entirely around the body of water to prevent undue evaporation.

3. Vegetative protection of stream banks, although often done independently, may be carried on in combinations with dams, jetties, dikes, riprapping, and other engineering devices.

Woodland practices may be particularly beneficial if planned with the welfare of wild animals in mind. Protection from fire and grazing is of tremendous value to the animal populations of woodlands. Other practices may be shaped to wildlife ends, for example:

1. In all operations designed to improve timber stands, the wildlife habitats should not be unnecessarily impaired. Usually they can be improved.

This involves leaving sufficient den trees, not cutting out too many "weed" trees, proper handling of excessive animal populations, and maintenance of borders, fire lanes, and uneven-aged stands.

2. In new woodland plantings, borders of small trees, shrubs, and vines of food-producing species should be incorporated in the planting. Mixtures of species should be used instead of

solid stands. Both practices increase not only the value of the habitat but the value of the forest for the production of wood products.

3. In the planting of windbreaks for control of wind erosion, low-growing shrubs that contribute cover and food should

Fig. 92.—Beaver planted by the Soil Conservation Service built this reservoir in a sparsely inhabited Washington watershed. It is equally efficient and less costly than a man-made one would be.

form the outer rows. Where necessary to protect the young trees from soil blowing, pending their firm establishment, rows of sorghum, Sudan grass, sunflowers, or corn may be planted between tree rows and on either side of the windbreak. While protecting the young trees, these plants furnish food for wildlife.

4. In cutting operations, wherever adequate winter cover is not supplied by normal undergrowth, the slash may be piled to afford protection for grouse, quail, rabbits, and other animals.

Special Practices. Planting of beaver has been carried on in several Western areas as a direct aid in the reduction of flood crests and silting (Fig. 92).

Establishment of feeding stations is encouraged in regions of heavy snowfall as a means of tiding wildlife over periods of critical scarcity of food until wildlife plantings have time to become effective.

Food patches are somewhat similar to feeding stations in their emergency aspects, except that they are regularly maintained by farmer cooperators with a special interest in game-bird production. Their establishment is often recommended to complete the wildlife-management program (Figs. 93 and 94).

Wildlife refuges may serve no direct function in erosion control, but they are valuable instruments of management in affording decimated game populations a chance to recuperate. Where eroding land is enclosed by such reservations, protection from cultivation, grazing, and fire aids in conserving both soil and water.

Various species of pond fishes may be established in farm ponds and reservoirs built for water conservation, and trout and many other game fish benefit through the prevention of stream sedimentation.

Good success is being had with the building on farms of small fish ponds for bream and bass especially. Recent experience has led to practical and effective methods of fertilizing ponds and otherwise managing farm ponds with great success. The yields of fish from a small pond properly managed are well worth while.

Questions

1. How does soil conservation benefit wildlife?
2. Give one or more examples of the relation of wildlife to environment.

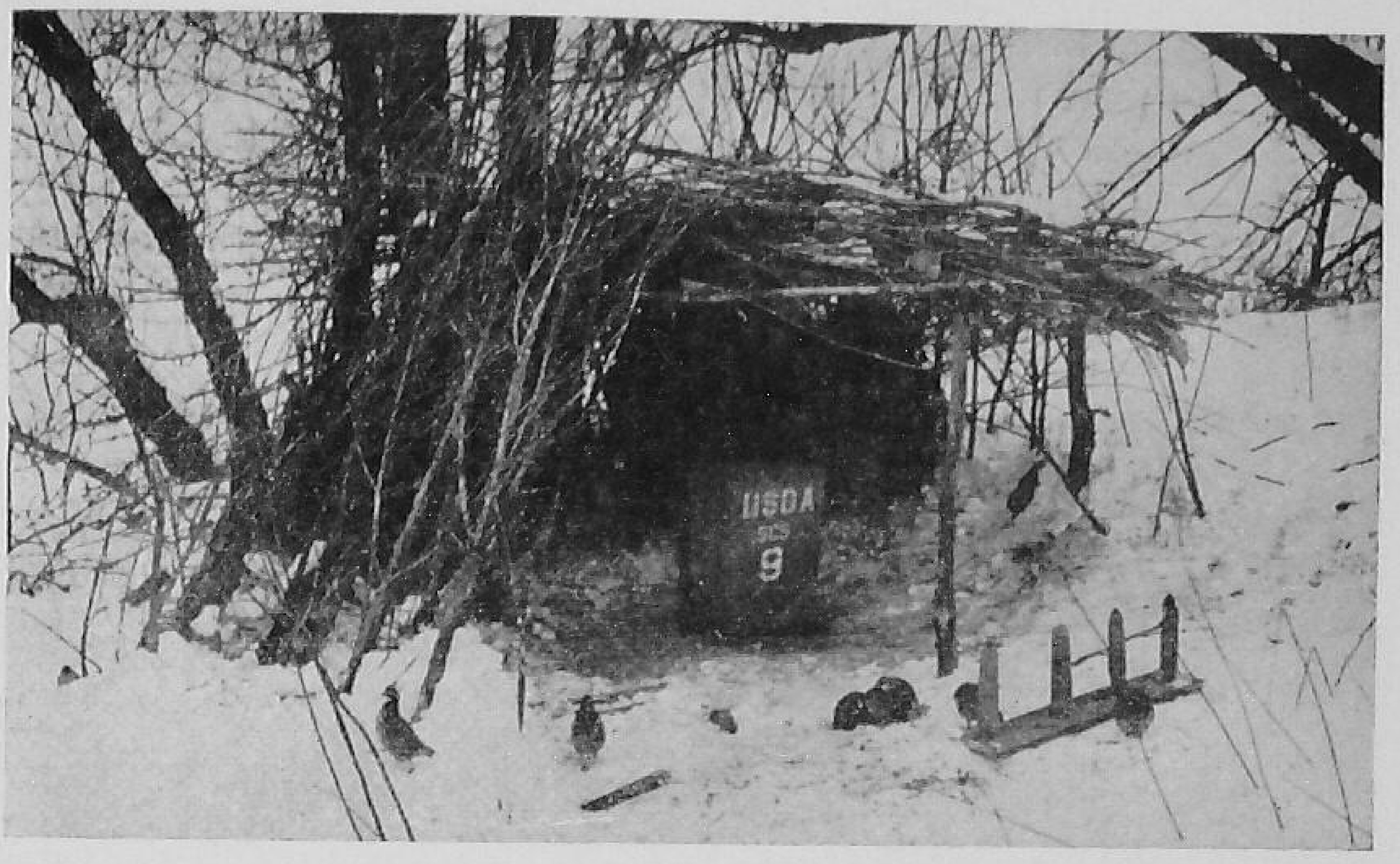

Fig. 93.—Bobwhite utilizing a feeding station built by Civil Conservation Corps boys under the direction of Soil Conservation Service in Minnesota.

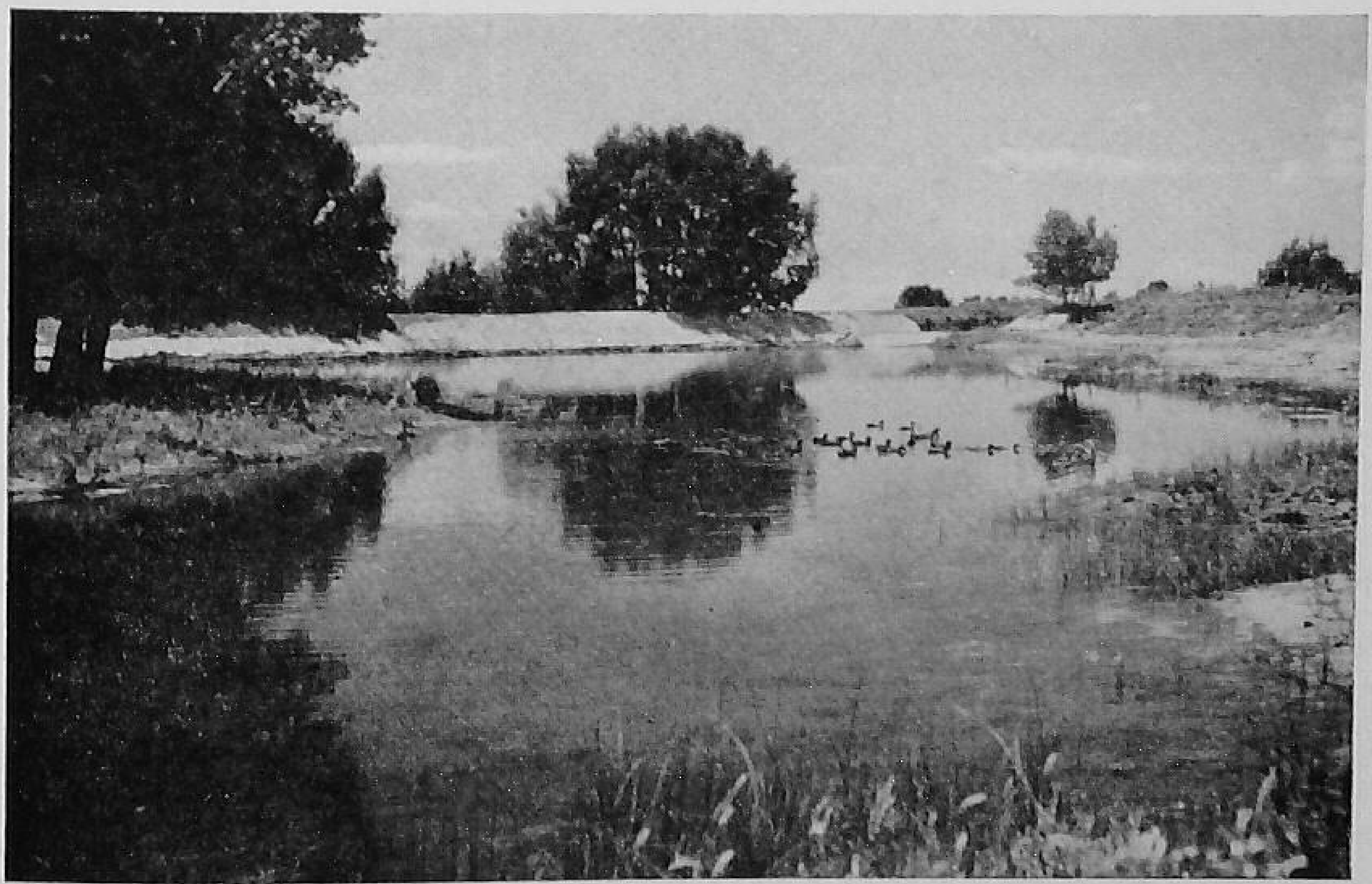

Fig. 94.—A flock of ducks on a reservoir built and fenced by the Soil Conservation Service in Texas. Hundreds of small reservoirs and stock water ponds have been constructed by the Service, particularly in the low-rainfall areas of the Great Plains and Colorado Basin area; on many of them wildlife is developing.

3. Which is the better habitat for wildlife, ungrazed or grazed woodland?

4. How does erosion affect fresh-water fish?

5. What is edge? Give examples.

6. Give examples of how soil conservation can help wildlife without minimizing the primary value of the method employed.

7. What results are being obtained with farm ponds?

8. What benefits are derived from control of stream bank erosion?

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CHAPTER 18

Small Dams for Water Storage

PRESENTING:

Specifications
Factors Determining Location
Materials and Installation

Small dams for farm and range use are usually not expensive, yet they add considerably to the value of the average farm or ranch, especially in low-rainfall regions. Besides supplying water and some recreation facilities, they play a part in controlling floods and improving conditions for wildlife.

Specifications. Although the basic requirements with respect to foundation, fill material, and spillway must be met in the construction of small dams, they need not always be built absolutely according to the precise specifications ordinarily set up for larger structures. Frequently, specifications have been so exacting that construction of small dams has been entirely impracticable. (Some flexibility based on common sense can be exercised in such situations.)

Small-dam specifications that demand masonry or concrete for spillways are often unreasonably restrictive. In all probability, many of these dams would serve their intended purpose if a good vegetated spillway were provided. Inasmuch as the spillway is not used ordinarily more than once or twice a year on many small ponds, an adequate native sod should afford ample channel protection. A good point to remember

in planning the construction of small dams is that they must provide an economical service.

Factors Determining Location. The main factors to consider in selecting the site for a stock-water storage area are the following: utility, foundation, storage capacity, quality of water, type and size of drainage area and probable runoff, spillway conditions, and local availability of construction materials.

Utility. The purpose for which a pond is built will have considerable influence on its location. If it is to be used for irrigation, the site must be above the area to be irrigated unless pumping is contemplated. If it is for stock use, drainage from the barnyard should not be allowed to enter the reservoir and it should be so located that the stock will not have to travel more than about a mile and a half for water.

Foundation. Subsurface conditions of every potential reservoir site should be tested by borings as a safeguard against an installation that will lose its water by seepage. Some soil types that are unsuitable for holding water may be made moderately watertight by adding clay and then permitting livestock to trample the surface. The area behind dams already built may be treated in this manner, but new ponds should not be developed where inspection indicates the probability of excessive seepage.

Storage Capacity. The purpose for which a reservoir or pond is to be constructed will determine the amount of storage capacity required. The need for maintaining an adequate and unfailing supply of water under all conditions will also influence the capacity determination. In making this determination, a sufficient factor of safety should be provided to allow for usage, evaporation, seepage, silting, freezing, and probable future needs. The most desirable type of reservoir is one with good depth and a minimum of surface area.

The rate of evaporation is an important consideration. Stock ponds must be deep enough to allow for evaporation losses; and generally, a depth of double the expected annual evaporation loss is a safe provision. During extended periods of drought, the evaporation rate may be increased by something like 50 per cent.

Drainage Area. The most desirable drainage area is one covered with vegetation. Many stock ponds, however, have been built where a large part of the drainage is from cultivated or heavily grazed land. Such ponds usually fill with silt in a short time, often losing their usefulness in a few years, unless the drainage area is used in such a way as to prevent erosion. Watersheds should be sufficiently large to provide enough runoff, on the basis of average annual rainfall, to meet the storage demands. Large drainage areas should not be used unless an adequate spillway can be provided economically.

It is frequently possible to control or minimize the silting problem by establishing a *grass filter* (well-grassed area to catch silt) immediately above the pond.

Quality of Water. Under certain conditions, the quality of water is a limiting factor in site selection. Highly saline water, for example, is unfit for stock, irrigation, or other purposes.

Spillway Conditions. Generally, the spillway should be carefully located and should have sufficient capacity to pass the largest runoff that is likely to occur within a 25- to 50-year period. A grassed spillway is most desirable from the standpoint of cost; but under heavy flows on steep grades, adequate structural protection should be provided. Since it is often difficult to establish good sod under arid or semiarid conditions, the use of natural spillways is desirable wherever possible in such regions. The natural sod in such spillways should remain undisturbed.

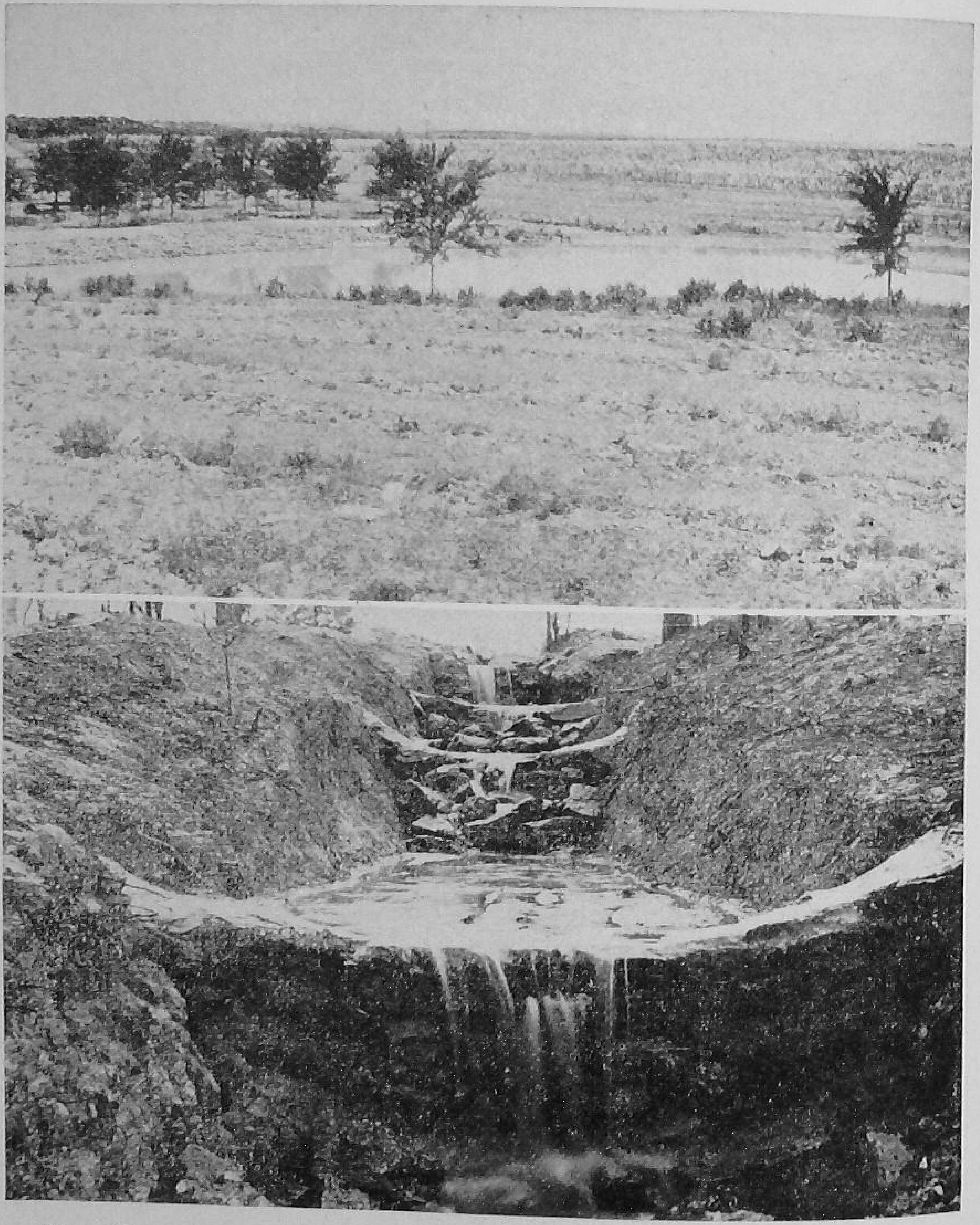

Fig. 95.—Above: farm pond in contour-furrowed pasture, eastern Oklahoma. Earth dam riprapped with rock from immediate locality. The water in such ponds is the only available stockwater on many farms. Below: series of simple rock-masonry dams to defer water entering head of gully. South Carolina Piedmont. (Work by Soil Conservation Service.)

Inasmuch as many states have regulations governing the construction of dams for water storage, it is always advisable to obtain advance approval of the plans from state authorities.

Materials and Installation. If a small dam is to be built economically, suitable materials should be readily available near the structure. Many dams fail because a sufficient quantity of compactible soil of relatively high density is not found near the dam and, as a result, less suitable materials are substituted. It is also desirable to have good rock for riprapping available near the dam site; but as already indicated, the lack of rock for this purpose is not always important enough to prevent the building of a dam (Fig. 95).

Questions

1. What are the principal factors governing location of small dams for water storage on farms and ranches?
2. Why is it so important to know the size of the drainage basin and the character of the foundation in building small dams?
3. What are the most critical structural requirements of small dams?
4. Can dams be built without approval?
5. What is a grass filter?

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CHAPTER 19

Stubble-Mulch Farming

PRESENTING:

Defects in "Clean" Plowing
Stubble-mulch, Surface Mulch System of Tillage
Use of Crop Residues for Surface Mulch
Stubble Mulch and Wind Erosion
Summer Fallow and Accelerated Wind Erosion
Implements for Stubble-mulch Farming

Defects in "Clean" Plowing. Farmers in many parts of the world have been doing too much "clean" plowing with their handy tools for turning soil upside down and burying every vestige of cover crops, crop residues, and other vegetation in order to prepare the ground for the next crop. Much improvement is needed in this phase of farming, in view of the fact that clean culture often amounts to unnecessary baring of the soil to the full erosive effect of wind and water.

Stubble-mulch, Surface Mulch System of Tillage. There is the remarkable case of Mack Gowder, in the upper Piedmont section of Georgia, near Gainesville, who cleared his land—mostly steep rolling sandy loam with red clay subsoil—30 years ago and now produces more per acre than when the land was freshly cleared from hardwoods-pine forest. Gowder's highly efficient type of culture is the result of (1) using a special narrow "bull-tongue" plow that does not turn the soil over—just plows through the soil, stirring it and leaving stalks, stems, and leaves on surface, (2) cultivating on the contour, (3) using

a good terracing system, and (4) practicing good soil-sustaining and soil-building crop rotations (Figs. 96, 97, 98, and 99).

What Gowder has been doing—with an exceptionally high degree of success—for 30 years is maintaining a mulch of vegetative litter on the surface of the ground, which litter has accomplished a number of very desirable things, without a single discoverable flaw in the practice, so far as the reports of many investigators go. Among the good things are

1. Protection of the soil from the direct impact of erosive rains.
2. Increased absorption of rainfall by the soil.
3. Maintenance of a relatively cool, moist soil condition favorable to development of beneficial activity by microorganisms.
4. Maintenance of a favorable humus supply in the soil.
5. Increased yields.

And much the same thing has resulted from such wise use of available vegetative material in various other parts of the country—materials like corn stalks, cotton stalks, wheat stubble, etc.

Use of Crop Residues for Surface Mulch. Crop residues consist of those parts of cultivated plants left in fields after harvest. Grain straw baled and sold is not considered a residue; but if it is scattered in the field by a combine, it is so considered. Corn stalks, cotton stalks, tobacco stalks, small-grain stubble, scattered wheat straw, refuse from potato plants, and pea vines are illustrations of crop residues. Overlooked weed litter or any other kind of vegetative litter—rotten hay or straw or hay or straw not needed for other purposes—whether grown in a particular field or brought into a field, can be used as mulch, provided the material is not foul with weed seed.

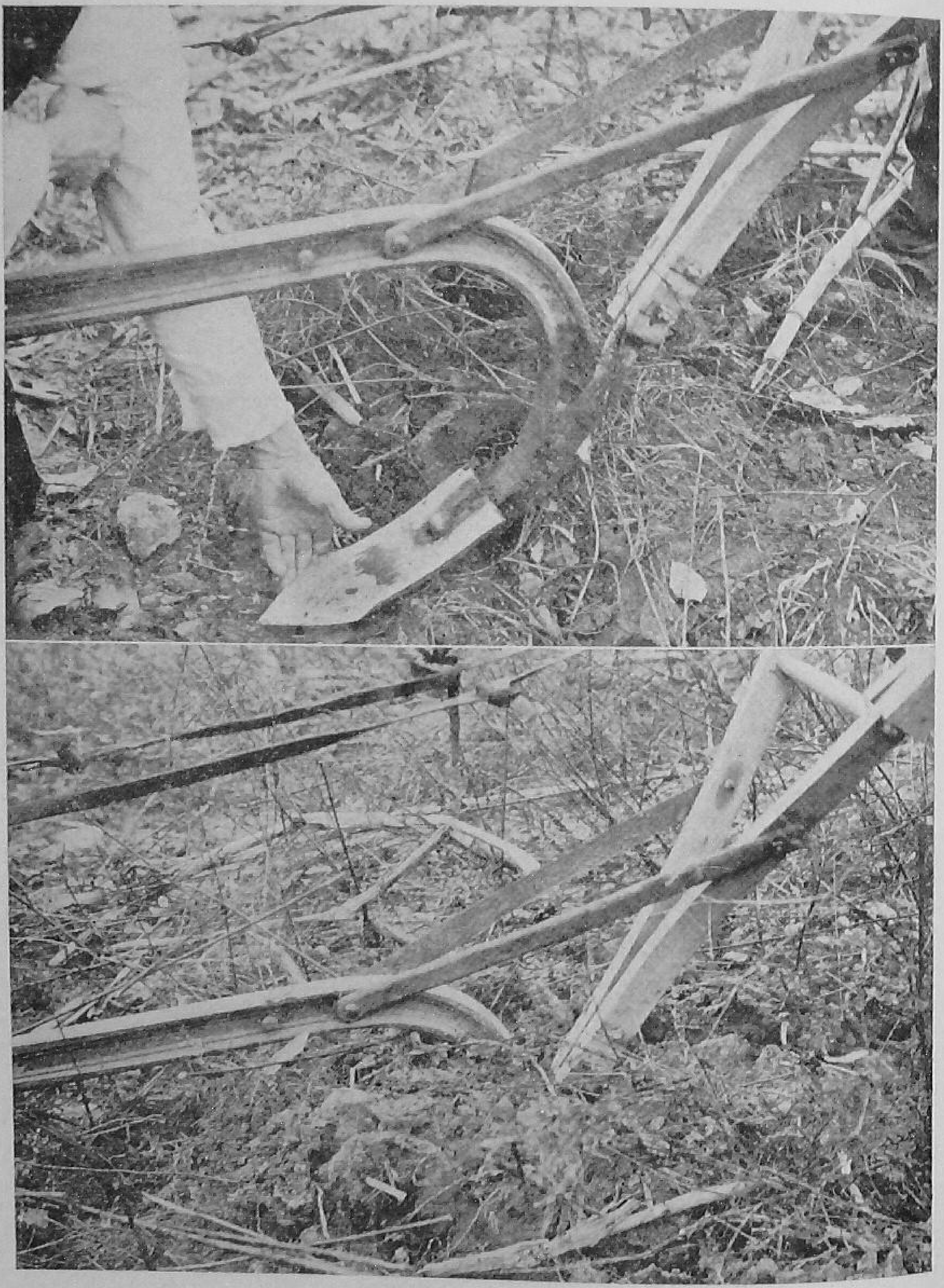

Fig. 96.—Above: bull-tongue plow used by Mack Gowder for cultivating without turning the soil over; below: plow in action.

Fig. 97.—Excellent contouring on Mack Gowder farm in the Georgia Piedmont hill country.

Fig. 98.—Vegetative mulch of cornstalks, and terraces on Mack Gowder farm near Gainesville, Ga.

In the Palouse wheat region of the Pacific Northwest, the former very common practice of burning wheat straw and stubble was found to be conducive to severe erosion. On the

Fig. 99.—Mack Gowder and his well-cared-for woodland from which the farm derives considerable income with sustained-yield cutting.

other hand, where this residue was partly turned under and the ground left in a cloddy condition, erosion, both by wind and by water, was greatly reduced. The method is also applicable to the wheat area of the Great Plains and probably to most of our small grain areas (Figs. 100 and 101).

The stubble and straw left in wheat fields harvested with combines frequently amounts to about 1,000 pounds per acre.

Fig. 100.—Burning wheat stubble—source of valuable organic matter—to facilitate plowing for next crop.

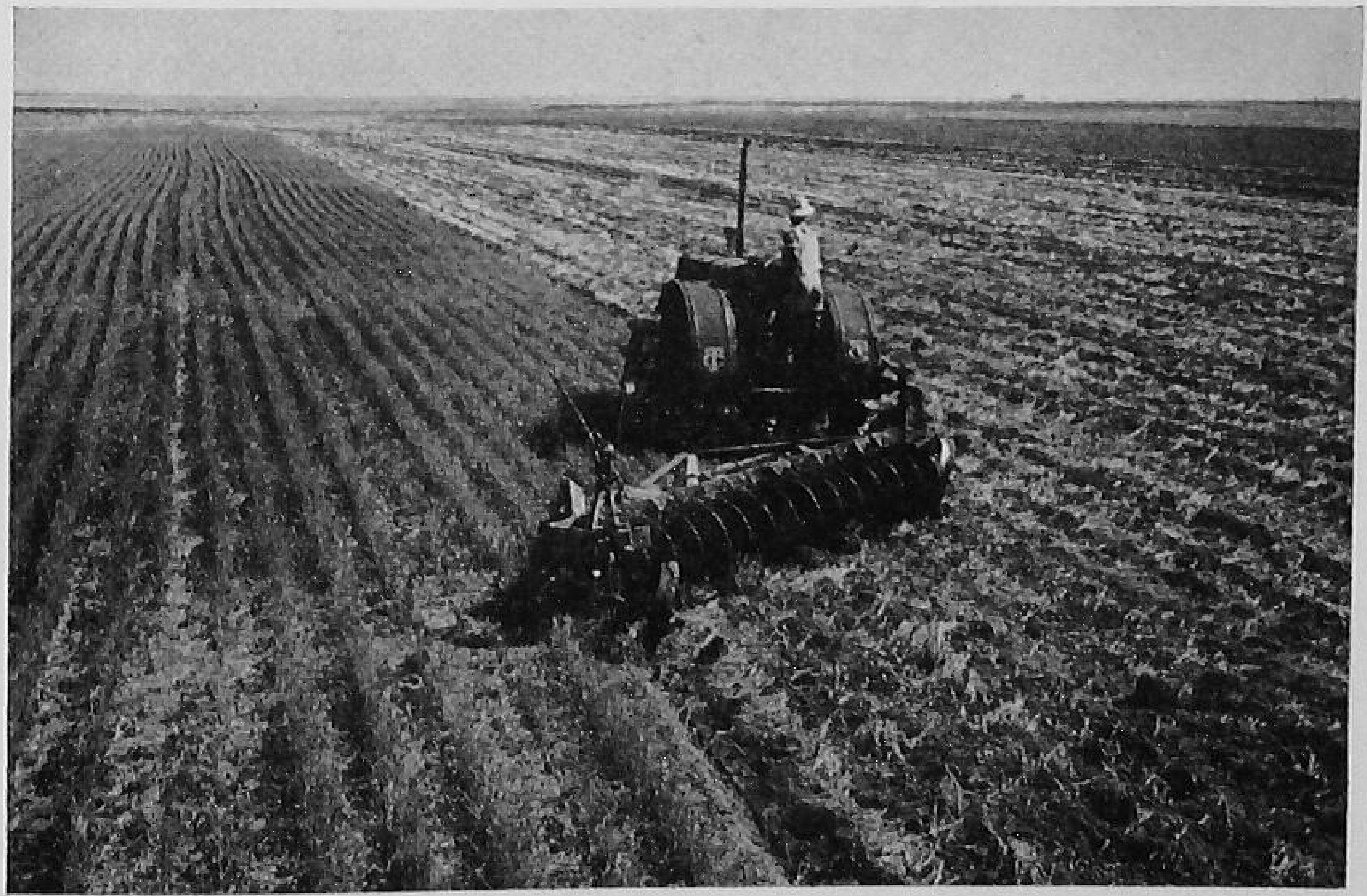

Fig. 101.—Disking wheat stubble to incorporate part of the residue with the soil and leaving the other part on the surface to control wind erosion.

This much straw can be incorporated with the soil without any marked effect on the yield of the next crop. But heavier amounts of such residue may, in subhumid regions like the Palouse and Plains, depress the succeeding yield. Insufficient experimental data are available on the subject, especially for a number of regions, but experience has shown that soil losses may be decreased or entirely prevented by plowing under part of the material and leaving part protruding from the soil or by leaving the bulk of the vegetative material on top of the ground, using appropriate tillage practices, such as some of the recently developed subsurface plows that destroy weeds without turning the soil upside down (Fig. 102).

When grass or other vegetative litter is driven deeply underground, as with the moldboard or turning plow, it cannot protect the surface. And fresh, loose soil exposed to the sun, wind, and rain on top of the ground is a rank invitation to trouble. The sun bakes the unprotected soil into an unfavorable condition, at least temporarily. When it is dry, it often falls loose and lifeless about the plow, so that wind can readily blow it away. And when any kind of rain heavier than a drizzle falls on it, soil washing results—sheet erosion and gullying—with an aftermath of muddy rivers, of floods, of silt laid down in reservoirs, harbors, and ditches. Where the slope is steep, there may be such a rush of water and soil downhill that crops are carried along with it. Also, the downhill wash of water and topsoil carries away both the added fertilizer and the natural plant food in the soil along with the whole body of the soil and all that it contains.

But still the moldboard plow will continue to have an important place in farming. It will be needed for plowing up (constructing) water-diversion ridges, terraces, and drainage ridges ("lands"), for use on certain lands of essentially

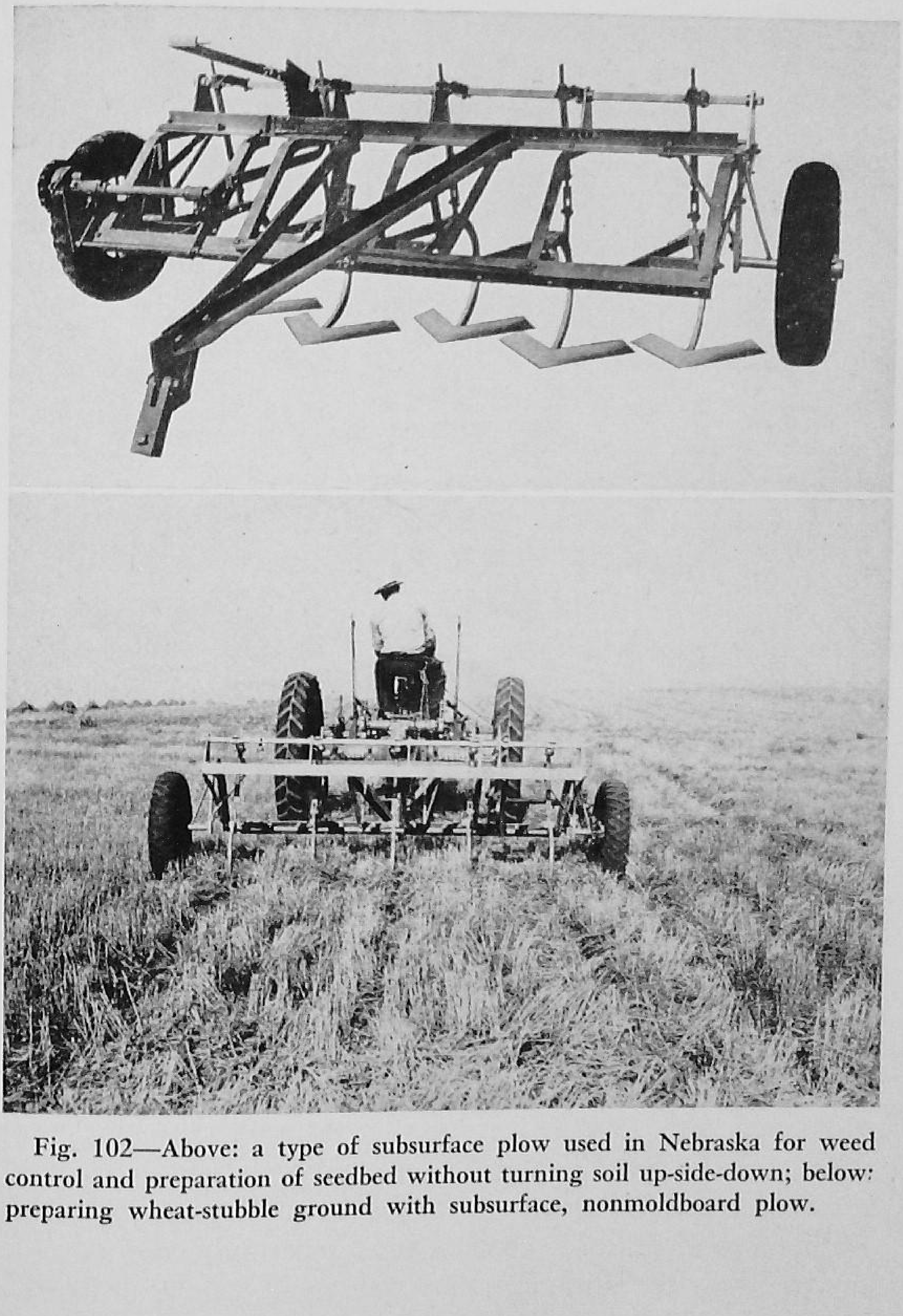

Fig. 102—Above: a type of subsurface plow used in Nebraska for weed control and preparation of seedbed without turning soil up-side-down; below: preparing wheat-stubble ground with subsurface, nonmoldboard plow.

level surface and on areas matted with persistent weeds and tough grasses, and for other purposes.

Stubble Mulch and Wind Erosion. Where wind erosion is serious, the stubble of such crops as sorghum or Sudan grass or even the entire plant when there has been little growth will catch and hold snow and retard or prevent soil blowing for periods of a year or more. In parts of Kansas, stubble of Sudan or sorghum has been found favorable for seeding sweetclover without any seedbed preparation. Oats and rye can be successfully seeded in cotton fields without plowing up the stalks even before all the cotton is picked. Some farmers report that small grain seeded on lespedeza stubble without preliminary plowing produces just as well as where the entire field is broken out. Good results have been obtained in various southerly localities by seeding small grain on lespedeza stubble without turning the soil over, that is, with light disking. Rippers or narrow tillage implements can be used for the same purpose. In Ohio at the Zanesville Erosion Experiment Station, promising results with alfalfa have been obtained by disking the seed into broomsedge, with fertilization. At the Coshocton water-study station, in the same state, good stands of alfalfa and clover have been established directly on grass by disking, rolling, and fertilizing.

Summer Fallow and Accelerated Wind Erosion. Under the summer-fallow system of growing wheat, the fallow fields have no surface protection during summer; and if they are used for spring-planted grain the following year, there is no protection through the intervening winter on until the grain is up to a condition of a good ground cover. Thus the bared areas are extremely susceptible to damage by erosion. In fields of high susceptibility to erosion, the farmer may wisely decide not to follow the summer-fallow system—at least as ordinarily practiced. With part of the last crop's stubble maintained as

a mulch, summer fallowing may be perfectly satisfactory. In localities where there is not enough crop residue to give adequate protection against erosion, some farmers use tillage implements that produce a cloddy surface, such as gives at least a little help. Another practice is to alternate, on the contour, strips of fallow and seeded ground.

Implements for Stubble-mulch Farming. Experiments are under way in many parts of the country to develop adaptable local practices for use of the stubble-mulch system. Excellent progress is being made, but more information is still needed on the subject. Implements to go with this kind of farming are being developed right along.

The "subsurface" type of plow now so commonly used in the northern Plains states and in the western part of the north-central prairie region is not a deep-going subsoil plow but a flattish plow with a good cutting edge that runs along some 3 to 5 or 6 inches beneath the surface so as to loosen up the soil and kill weeds by cutting them off. Such plows have no attachment for turning the soil over, as do a moldboard plow or a disk set for turning over the soil.

Questions

1. What is "clean" plowing?
2. What are the advantages of keeping a mulch of vegetative litter on the surface of cultivated fields?
3. Give examples of practical use of crop stubble in erosion control.
4. What effect does surface mulch have on microorganisms?
5. How can stubble be used against wind erosion?
6. What are some of the local deficiencies of summer fallow?
7. What general type of implement is called for under the surface-mulch system of farming?
8. What is immediately needed in the field of mulch culture?

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CHAPTER 20

Farm Drainage

PRESENTING:

How Drainage Affects Farm Enterprises
Field Ditches for Surface Drainage
Ditching with Machinery
Ditching with Explosives
Underdrainage
Planning a Tile Drainage System
Installing a Tile Drainage System
Draining Seepy Hillsides
Maintenance of Farm Drains

About one-fifth of the cultivated acreage in farms has been ditched or tile drained. A somewhat smaller area is not giving full returns because of imperfect or poor drainage. Part of the drained land has gone back to varying unfavorable conditions because of the choking up of ditches with silt and vegetation and the filling of tile drains with soil washed in from adjacent slopes. Where the damage is exceedingly serious, farmers generally recognize the problem and understand the needs for its correction—although they cannot always cope with it. Too often they do nothing beyond hoping the following season will be more favorable.

How Drainage Affects Farm Enterprises. Land that is definitely better suited to wildlife than agriculture should not be drained, especially where occurring in tracts of important extent. Generally speaking, acid peat lands should be utilized for wildlife or purposes other than for the growing of the

more common farm crops. Peat land should not be confused with muck. Peat is composed largely of the remains of plants, so that the material on drying is highly susceptible to burning. Muck lands contain more mineral material, usually enough to prevent rapid burning.

The hope for better seasons frequently is realized, and a fair crop makes many forget that future seasons will often be unfavorable. A poorly drained field, which in some seasons is productive and in others is not, may be more detrimental to a farmer's success than nonarable swamp. When a field is plowed, planted, and cultivated and then no crop is harvested, not only is that land a costly failure, but the labor, fertilizer, and seed likewise are lost.

Benefits from Drainage. Waterlogged soil is cold natured because it takes more heat to warm water than to warm a like quantity of soil material and very little is required to warm the air that replaces the moisture drained from a soil. Bacteria necessary to condition soil constituents for plant food are lacking in wet land or are deficient in numbers, because they require air and warmth. A soil that is wet for long periods is apt to become hard and dense on drying. Most soils when plowed wet tend to dry out to unfavorable hardness, resistant to penetration by plant roots (puddled soil).

Drainage makes land ready for plowing and planting earlier in the spring and permits cultivation sooner after rains than is otherwise possible. In a well-drained soil, beneficial activities of various kinds operate more effectively and plants grow faster and stronger.

Drainage of wet spots makes it possible to plow, plant, or cultivate the entire field at the same time instead of leaving the wet places to dry out. And better and more uniform yields usually are obtained over entire fields with expenditure of less time and labor. In a soil that is wet nearly to the surface dur-

ing spring and early summer, the roots of crops spread out near the surface. Later, with summer droughts, the water table may fall below this root zone, causing crops to suffer. In well-drained soil, the roots go deeper so that plants are better able to withstand drought.

In areas of organic soil, such as the peat lands of the Florida Everglades (alkaline peat), it is necessary to control the water level in order to prevent burning, reduce subsidence by oxidation, and hold moisture high enough in the soil—but not too high—to allow proper root development. Such an operation calls for a system of carefully placed ditches and dikes, with pumps to lift or lower the water table in order to meet such requirements.

Field Ditches for Surface Drainage. The simplest and cheapest method of drainage is by shallow ditches that follow the depressions through fields. The best location for these ditches can readily be determined by the farmer after a rain, when water is standing on the ground. Ditches can be made at any time when men and teams are not engaged in other work. In this manner, the low spots in a field can gradually be brought into cultivation so that with a small outlay of cash, a farmer can put his land in much better condition as far as surface drainage is concerned. Benefits will more than repay the labor and other costs. Drainage of this kind, however, is chiefly effective for removing surface water. Deep drainage requires the installation of deeper ditches or tile drains.

Field ditches are of two principal kinds: narrow ditches with nearly vertical sides and V-shaped ditches with moderately sloping sides. Narrow ditches are used in localities where large machinery is not employed extensively in farming, so that cutting the land into small fields does not seriously interfere with farming operations. V-shaped ditches are more desirable where

farming with large machinery is practiced, as they can be crossed with such equipment and their presence does not interfere so much with farming operations.

Ditching with Machinery. Where the ground is comparatively free from stumps and rocks and sufficiently dry to afford a footing for teams, an ordinary plow and a slip scrape can frequently be used in constructing shallow field ditches such as are normally required for surface drainage. However, if there is much work of this kind to do, it is generally advisable to use one of the smaller types of ditching plows. With such plows, V-shaped ditches from 2 to $2\frac{1}{2}$ feet deep can be dug economically, the plow being drawn back and forth by horses or tractor until the ditch is of proper size. In addition to digging ditches, such plows can be used for building terraces and grading roads.

Various types of machines have been designed for constructing large ditches.

Ditching with Explosives. While ditching with explosives is possible under almost any condition, the method usually is economical only for making small ditches or cutoffs in stream channels—in soil other than gravel or dry sand. The most economical size of a dynamite ditch is about 3 feet in depth and 8 feet in top width. Much larger ditches can be built in this manner, but the cost of excavation usually limits this method to smaller ditch jobs. The ideal material for dynamite ditching is wet alluvial soil, firm but not too stiff and free from stumps and large roots. Many excellent ditches have been blasted under conditions quite different from these but at increased cost. Where conditions are such that the work is adapted to any one of the several types of ditching machines, it generally is not advisable to use explosives, but usually it is much cheaper to dig ditches this way than with hand labor.

To blast a ditch with dynamite, a number of small charges are placed in a series of holes along the center line for a ditch

less than 10 feet wide and in two rows or in large post holes for wider ditches. The charges are usually exploded by the propagation method rather than the electric method. In the propagation method, the charges are so closely spaced that the detonation of one will explode the others. In the electric method, the charges are connected to an electric blasting machine and all are discharged simultaneously. The first method has the advantage of being cheaper, but it can be used only in wet soils. With the electric method, the charges are more certain to explode, and therefore this method is sometimes used for special conditions.

There are two types of explosives in general use for agricultural purposes: the "straight," or nitroglycerin, variety, and the "extra," or ammonia, type. Straight dynamite is sufficiently sensitive to cause the explosion to propagate itself from charge to charge, so that the whole ditch may be blown out with one detonator. The ammonia type is so insensitive that each charge must be detonated separately by electric caps. Various strengths of charge are used depending on conditions. Generally, the straight dynamite is 50 per cent nitroglycerin or stronger. The ammonia or nonpropagating variety is of less strength.

The size of the charges, the depth, and the distance apart depend on the conditions. For each size of charge, there is a definite depth at which a broad, clean-cut, U-shaped ditch will result and that will give the maximum amount of excavation per pound of explosive used. When a charge is placed too deep for its strength, loose dirt will be left on the sides of the ditch; and when not deep enough, the full power of the dynamite is not used.

The proper size and spacing of charges to give a clean-cut ditch of the desired depth must be determined experimentally for each set of conditions. This can best be done by firing a

number of single charges; and when a size of charge is found that gives a smooth crater of the desired depth, a little less than half the diameter of the bottom of the crater will be the proper distance between charges for the electric method. The proper distance between charges for the propagation method can be found only by trial. For a ditch 3 feet deep and 8 feet wide on top, in a saturated soil, it will be found that charges about as follows will be required: For the propagation method, 1 stick of 50 per cent straight dynamite, in holes 30 inches deep and 18 inches apart; for the electric method, 2 sticks of 40 per cent extra dynamite, in holes 30 inches deep and 30 inches apart.

The cost of ditch excavation by dynamite varies greatly. Under favorable conditions, a pound of dynamite will blow out from 1 to 2 cubic yards of earth, making the cost for the explosive from 15 to 30 cents per cubic yard. Very little labor is required for such ditching. A gang of four men can load and shoot about 600 linear feet of single-row charges per day. It is usually necessary to remove debris and smooth the sides and bottom of the ditch with shovels after blasting. If done promptly, the work should not cost more than 1 cent per linear foot of ditch. This method is also useful for straightening streams.

Directions for handling, loading, and firing charges for ditches can be obtained from the manufacturers of explosives.

Underdrainage. Underdrainage has to do with the removal of excess water from greater depths of soil than those referred to above. It is usually accomplished by tile pipes through which the water drains off slowly.

In some localities where the soil is not too stiff, "mole" drains have proved satisfactory for short periods. Such drains are constructed by a mole plow, consisting of a short cylinder of iron about 4 inches in diameter with a sharp point, connected to a beam by a sharp shank about 4 feet long. The mole,

attached to the source of power above by a shank, is pulled along the course of the desired drain with the shoe at a depth of 2 to 2½ feet below the surface. The narrow cut made by the shank closes after the operation; that made by the shoe remains open and acts as a drain. In rocky soils or where stumps and other obstructions occur or in sandy soils that cave or "flow" readily, this type of drain is not feasible. In muck and peat lands, mole drains have proved fairly effective for 5 years or more before the fields had to be remoled.

The tile drain is the best underdrain. It consists of tile laid in a narrow ditch, in a continuous line, and on a grade only steep enough to cause the water to move on out. The water enters the tile line through the joints. Porous tiles are no more efficient than impervious tiles and are likely to be soft and easily broken.

Planning a Tile Drainage System. The first essential for a tile drainage system is a suitable outlet. This may be a natural watercourse, a large open ditch, a small field ditch, or another tile drain. It is important that the outlet be large enough to carry the flow reaching it without submerging the tile for too long a time during periods of heavy rainfall. The ideal outlet should permit a free flow from a tile drain at all times.

In most cases, an adequate natural watercourse or drainage ditch is available to carry away the water discharged by a tile system. Generally, the outlet channel should be provided before the system of underdrains is installed. On flat areas of restricted drainage outlet, the construction of outlet ditches sometimes requires the cooperation of a number of interested landowners. A majority of the states have drainage laws that provide for such cooperation, usually through the organization of drainage districts having authority to construct and maintain outlet ditches or drains and to assess each landowner within the

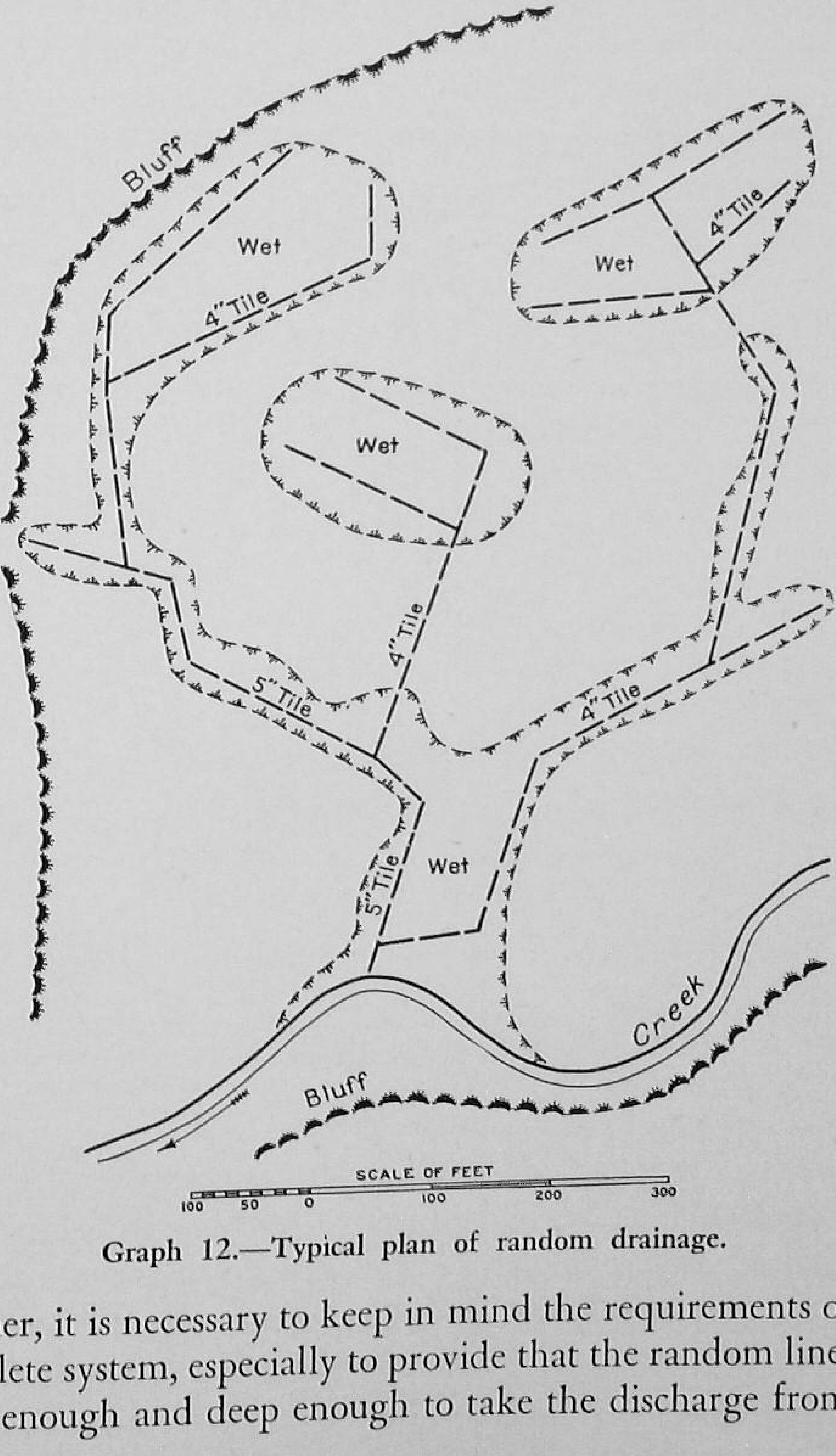
district a share of the cost proportionate to the benefit that he derives.

Location of Drains. The location of tile drains is controlled largely by the location of the outlet and the topography of the area to be drained. Where the land is more or less rolling, a farm may sometimes be thoroughly drained by laying random lines (*random system*) of tile where the soil is too wet for profitable cultivation (Graph 12). In such cases, the drains should be located in the course of the natural flow or so as to serve the portions of the field that are in particular need of drainage.

Where the land is uniformly too wet for cultivation, it is advisable to construct a *complete system* of underdrainage, that is, a system of main-outlet drains with parallel lateral drains under the whole area. In general, the main drains should follow the courses taken by the surface water in passing off the land during periods of heavy precipitation. The laterals should be straight and run in the general direction of the greatest slope; they should be arranged in groups of parallel lines laid at such intervals and at such depths as the soil requires. A system of short mains with long laterals is most economical, as the mains drain the land for a certain distance on each side and the laterals through this drained belt serve only to conduct the water to the mains. One main should serve as many laterals as possible in order to keep the number of tile outlets at a minimum, for outlets always require more or less attention if the drains are to operate efficiently.

Where entire fields would be benefited by underdrainage and the landowner does not have sufficient money available to construct a complete system, it is frequently possible to drain those parts needing drainage most with a random system and leave the balance of the work until a later date. The results obtained from the drains first installed can be carefully studied

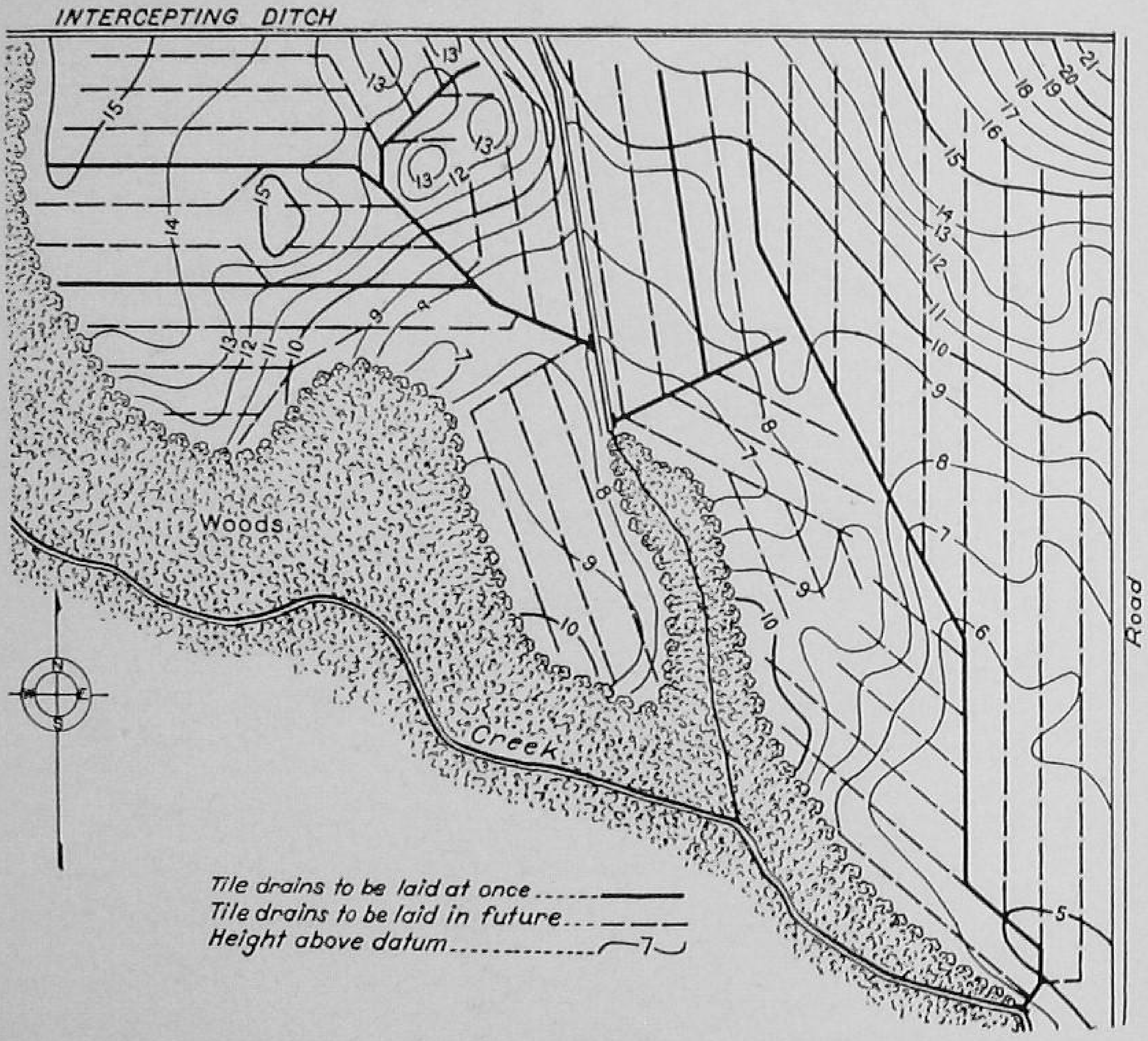
and the location of additional needed drains safely determined from this information. In constructing a random system in this



Graph 12.—Typical plan of random drainage.

manner, it is necessary to keep in mind the requirements of the complete system, especially to provide that the random lines are large enough and deep enough to take the discharge from the

future laterals. Graph 13 illustrates a comparatively level field to be drained first by random lines of tile designed to be used as the mains in a complete drainage system that will be constructed later.



Graph 13.—Random drainage system with provision for complete drainage to be installed later.

When the area to be drained is of considerable size and nearly level, it is always advisable to employ a competent drainage engineer to make a survey of the area, locating and staking out the drains. Where the land has plenty of fall and the areas to be drained are small, the landowner frequently can locate the drains during wet periods and construct them at such times as the general farm work permits.

Depth and Spacing of Drains. The proper depth of tile drains and the distance apart are determined largely by the texture and structure of the soil—its grain and porosity. Normally, the ground-water level is lowered between drains in a curved line, the highest point being midway between the drains. The spacing and the depth should be such as would reduce, as nearly as practicable, the top of the ground water between the tile lines to an elevation most beneficial to plant growth within 24 hours after a rain.

The rapidity with which a drain lowers the ground-water curve depends on the ease with which water percolates through the soil. The amount of sand in the soil often is one of the elements affecting the rate of percolation. In sandy soils, drains usually may be placed deeper than in dense clay and accordingly may be spaced farther apart. In tight (dense) clay, the movement of soil water is sluggish and underdrains must be placed at less depth and closer together than in soils of more open character.

In clay soils, it is generally necessary to place the drains from 40 to 70 feet apart and from about 27 inches to 3 feet deep. No tile should be laid less than 27 inches deep; that is, the bottom of the trench on which the tile is laid should be at least 27 inches below the ground surface. In the more open soils, such as sandy loam, it may be sufficient to space drains 80 to 200 feet apart and make them from 3 to 4 feet deep. A spacing closer than 50 feet makes drainage so expensive that it usually is not recommended unless the land is to be used for trucking or some other type of crop from which the returns are large.

Size of Tile. The size of tile for the main and submains of a tile system is determined largely by the area drained, the surface conditions, the porosity of the soil, and the grade, or fall, available for the drain. The required capacity of a drain is nearly proportional to the acreage from which the water comes,

other conditions being the same. An area from which all the water must be removed by the underdrains will require larger tile than one that has good surface drainage because surface channels carry off a large part of the water during a storm and underdrains then have to provide for only the part that seeps into the soil. The capacity of a tile line increases with the rate of fall along the drain, being about twice as much at a fall of 4 inches in 100 feet as at 1 inch in 100 feet. Therefore the greater the grade, or fall, the smaller the size of tile required.

Four-inch tile is the smallest size that should be used for land drainage. Smaller sizes are more difficult to lay accurately and are much more easily clogged when a small amount of silt gets into the line. A 4-inch tile has fully twice the carrying capacity of a 3-inch tile, and the difference in cost is not sufficient to warrant the risk involved in using the smaller drain. Table 10 shows the comparative capacities of different sizes of tile lines.

TABLE 10. COMPARATIVE CAPACITIES OF TILE

One drain	Will carry the discharge of
Diameter of tile, in.	Diameter of tile
5	Two 4-in.
6	Three 4-in. or one 5-in. and one 4-in.
8	Six 4-in. or two 6-in. or three 5-in.
10	Eleven 4-in. or one 8-in., one 6-in., and one 5-in.
12	Eighteen 4-in. or one 10-in., one 8-in., and one 4-in.

Experience indicates that where no surface water is admitted to the underdrains, tile systems in ordinary loamy soils generally should be designed with sufficient capacity to remove ¼-inch depth of water over the area drained in 24 hours. In some of the more pervious soils that permit the water to pass through rapidly, such as loose sandy loam, it is advisable for

the drains to have a capacity of $\frac{3}{8}$-inch depth of runoff per 24 hours. When surface water is admitted to the underdrains, as

TABLE 11. AREAS FROM WHICH $\frac{1}{4}$-INCH RUNOFF PER 24 HOURS CAN BE DRAINED BY TILE MAINS

Size of tile, in.	Fall per 100 ft.			
	$\frac{5}{8}$ in. or 0.05 ft.	$1\frac{1}{4}$ in. or 0.1 ft.	$2\frac{3}{8}$ in. or 0.2 ft.	$3\frac{5}{8}$ in. or 0.3 ft.
	Acres drained			
4		6	9	12
5	8	12	17	21
6	13	20	28	35
8	31	43	62	75
10	55	79	110	138
12	90	128	180	220
Size of tile, in.	$4\frac{3}{4}$ in. or 0.4 ft.	6 in. or 0.5 ft.	9 in. or 0.75 ft.	12 in. or 1.0 ft.
	Acres drained			
4	14	15	19	22
5	25	28	34	40
6	41	45	56	64
8	87	98	120	138
10	158	177	215	250
12	255	280	345	410

through surface inlets, the size of the tile should be increased so as to carry a runoff of $\frac{3}{4}$ to 1 inch per 24 hours.

Table 11 gives the area in acres from which $\frac{1}{4}$ inch of water will be removed in 24 hours by various sizes of tile laid at

grades ranging from $\frac{5}{8}$ inch per 100 feet to 12 inches per 100 feet. When $\frac{3}{8}$-inch runoff is to be provided, two-thirds of the areas given in the table should be used. Where surface inlets will admit large quantities of surface water, the tile will give drainage to but one-fourth of the areas stated in the table.

Installing a Tile Drainage System. Draintile should be circular in cross section and approximately straight. The inside should be smooth, and the ends regular and smooth enough for making close joints. Tile smaller than 10 inches in diameter should have a length of 12 inches; large tile may be 18, 24, or 30 inches in length, according to the size.

Selecting Tile. Good tile should be free from visible masses of lime such as would slack and start disintegration. Tile should be free from cracks that would decrease the strength materially and when dry should give a clear ring when stood on end and tapped with a light hammer. It is important that tiles have sufficient strength to withstand the pressure to which they are subjected.

Clay draintiles are classified as either common or vitrified. The former are made from common brick clay which, when well burned, makes a good quality of building brick. Vitrified tiles are made of ground shale or of a high-grade clay, frequently mixed with common clay, and in some instances are salt glazed. They are stronger and less porous than the common clay tile and are usually more resistant to frost action. Either kind, when well made, is satisfactory for farm drainage.

Concrete tiles have been extensively used in the Middle West. When properly made, they have proved satisfactory in most soils where alkali salts are not present. Such tile must be made of clean sand and gravel, properly mixed and cured. To make good concrete tile, proper equipment and careful supervision by men experienced in such work are required.

Importance of Correct Levels. It is important that there be no sags in a completed tile drain. Any depression is likely to cause a settling of silt in the tile, which will result in partial or even total obstruction of the drain. Where the available fall is slight, determination of the levels on which construction work is based must be done accurately. For this reason, it is advisable that the preliminary levels be determined with an engineer's level where practicable. The less the available fall the greater the necessity for accurate work.

When the fall is 3 inches or more per 100 feet, fairly good results can be had by establishing the tile grades with an *A*-frame used in connection with a carpenter's level.

Digging the Trench. Trenching should always begin at the outlet and proceed upslope. For small tile, trenches are usually dug 10 to 15 inches wide, according to the depth, and with practically vertical sides. The trench is dug with a tile spade to within 1 or 2 inches of grade, and then the bottom is cleaned out to grade with the drain scoop. Standing in the trench ahead of the tiles that have been laid, the workman draws the scoop toward him, leaving the trench bottom smooth and rounded to fit the lower part of the tile. Care should be taken not to excavate below grade.

Where the amount of work to be done is large and labor scarce, it is frequently advisable for the landowner to purchase some form of tile-trenching machine or to have the drains constructed by a contractor who has such a machine. The cost of trenching by machinery is usually cheaper than that by hand labor. The other main advantages of machine work over hand labor are that fewer men are required and the work is completed more rapidly.

Power-operated tile-trenching machines have been perfected in recent years so they will lay tile with a uniform grade. Ditching plows will excavate trenches suitable for smaller sizes

of tile. They can frequently be used to advantage in digging the top 18 inches or 2 feet of the trench. However, hand labor is necessary to dig the trenches to grade after such plows have been used. Power-operated trenching machines are of two general types: wheel excavators and endless-chain excavators.

Laying the Tile. Tile laying, like trenching, should begin at the lower end, or outlet, and progress upstream, following closely the excavation of the trench. In placing the tiles, they should be turned until the ends fit together. If a tile is crooked or has irregular ends, it should be turned until it fits tightly at the top, the open space being left at the bottom. Where, owing to irregular ends, a crack or opening of $\frac{1}{4}$ inch or more must be left at the top or sides, it should be covered with pieces of broken tile, strips of tar paper, or, in some sandy soils, cement mortar.

Tile up to 6 inches in diameter can be placed either with a tile hook by a man on the trench bank or with the tile scoop by the man who is finishing in the trench. It has been found that, with unskilled labor, the best results are obtained if the man using the tile scoop works backward up the trench, laying the tile as fast as he finishes the grade.

If the trench has been dug below grade in dry materials, the bottom can be built up to grade with moist earth, well tamped. In a wet, soft trench, it may be advisable to lay the tile on plank bedded at grade. Where saturated fine sand or sandy loam is encountered, it is necessary to prevent the soil from washing into the tile through the joints by wrapping the joints with cloth or tar paper. In laying tile through quicksand, it is well to have the assistance of a man experienced in such work.

All tiles that are cracked, soft, or poorly shaped should be laid aside; they are not wasted, unless there is an excessive number, as it is necessary to have broken tile to patch junctions and poor joints.

The tiles should be covered the day that they are laid with loose earth to a depth of 4 to 6 inches, so that they may be held in place. This should be done carefully in order not to displace the tile, that is, turn them out of line.

Trenches should be filled soon after the tiles are laid. For this purpose, a plow can be used with two horses, one on either side of the trench, attached to a long evener. One side is plowed while going in one direction, and the other side on the return trip; usually two rounds of the plow are sufficient to backfill a ditch. A scraper made from a 2- by 12-inch plank, 4 feet long, can be used to good advantage in many cases. The horses in this case work at right angles to the trench, scraping in the earth piled on the bank. If this method of backfilling is to be used, it is advisable to throw all the earth dug from the trench on one side rather than on both sides. Road-grading machines and farm tractors can also be used for backfilling trenches.

Protecting the Outlet. Tile outlets are often damaged by washing out and caving unless adequately protected. A headwall of brick, stone, or concrete may be built, extending below the ditch bottom, or a length of corrugated metal pipe used that will extend beyond the slope of the ditch bank. A cushion of stone or concrete should be built in front of the outlet to prevent erosion of the channel. Ordinarily, surface water that follows the depresion over the tile line should be diverted so as not to discharge over or around the drain outlet.

Draining Seepy Hillsides. Wet areas along hillsides usually are caused by an impervious subsurface layer that stops the downward movement of the water (*percolation*) so that troublesome wet places develop, often miry and useless. This condition can be corrected by laying an intercepting tile drain just above the place where the ground becomes wet and deep enough to cut off the water flowing along the top of the impervious

layer. The drain should run across the slopes as nearly parallel to the seepy place as possible.

Maintenance of Farm Drains. Any drain that is to operate efficiently must be kept clean. Tile drains with good outlets, if properly constructed, rarely become clogged. The condition of the soil along a drain a few days after heavy rains always indicates how the drain is working. If wet spots occur, the water is not being carried off properly. A hole or cave-in above a tile line indicates that a tile has been either broken or displaced. When this occurs, immediate steps should be taken to repair the line; otherwise the entire drain above the clogged part may become filled with silt, making it necessary to re-lay that part of the line.

Open ditches and the outlet channels for tile drains and the lower ends of the tile lines should be inspected frequently, and all weeds, grass, briars, willows, silt, trash, or refuse of any kind that obstructs the flow of water should be removed. If this is done at frequent intervals, the cost is comparatively small; if the drains are allowed to deteriorate, the cost of repairing them or redigging the ditches may equal the cost of the original improvement.

Questions

1. Explain how drainage affects the farm enterprise.
2. Name three major benefits to be derived from farm drainage.
3. What principal water conditions must be controlled in the cultivation of peat land?
4. Define surface drainage. Underdrainage.
5. What are the principal governing conditions controlling ditching with explosives?
6. In planning tile drains describe briefly five main points that govern correct installation. What is a random system of tile drains? Complete system?
7. What is meant by seepy land?

8. What are the essentials of maintaining farm drains?
9. Why do so many farmers fail to drain wet spots in fields?
10. What lands should not be drained?
11. What effect does drainage have on the shape of the surface of the water table?
12. What determines the size of tile drains?

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CHAPTER 21

Farm Irrigation

PRESENTING:

Location and Extent of Irrigation Farming
The Irrigated Farm
Source of Irrigation Water, Supply, and Public Control
Efficient Use of Irrigation Water
Land Leveling
Overhead Irrigation

Irrigation has to do with the artificial application of water to supplement rainfall as an aid to crop production. It ranges from the sprinkling of a city lawn or flower garden during a brief dry spell to supplying all or nearly all of the water required by the crops on large farms in regions of low rainfall.

Irrigation by sprinkling is an important practice in growing vegetables in various parts of the East, as in New Jersey and on Long Island. There is increasing interest in the use of irrigation for various crops, even pastures, in a number of high-rainfall areas as a means of overcoming the drought damage that occurs somewhere almost every year.

Location and Extent of Irrigation Farming. Irrigation farming is mainly confined to the semiarid sections of the 17 Western states. In Louisiana and Arkansas, water is held on rice fields for considerable periods, at least partly for the purpose of controlling weeds. In the Western states, a great variety of crops are grown under irrigation, ranging from native hay meadows irrigated with simple practices to vegetables and

fruits irrigated with more complex, highly developed systems of water supply and distribution.

According to the census, 21 million acres were farmed in the United States as irrigated land in 1940. Of this, 20,300,000 acres were located in the Western states.

Although many farmers and ranchers have developed their own water supplies, most Western irrigation developments have been the outgrowth of group action, and each project is more or less peculiar to the lands that it serves.

The Irrigated Farm. In selecting land for irrigation farming, it is important to consider such factors as soil and subsoil characteristics, slope, surface irregularities of the land, markets, roads, living conditions, and climate.

Land Surface. Almost any land can be irrigated; but if the surface is too steep or too rough, the difficulties are likely to be so great that the cost may be unreasonably excessive. An ideal field for irrigation is one having a smooth surface—without hummocks, rocks, or depressions—and a slope of about 0.3 to 1.5 per cent (½- to 3-foot fall in a linear distance of 100 feet). Ordinarily on such land, very little leveling is required and water can be applied easily. Slopes up to about 3 to 5 per cent can be irrigated without much difficulty. But land having a declivity greater than 5 to 10 per cent, depending on the soil and crop, generally calls for extra precautions. On porous sandy soil, grass and grass-legume mixtures usually can be safely irrigated on somewhat steeper slopes, provided the water is carefully handled. Seldom should irrigation be practiced on slopes as steep as 12 to 15 per cent.

Even on nearly level land, the cost of smoothing the surface of minor inequalities for efficient distribution of water may be considerable. The surface must be so smoothed off that there are no troublesome pockets for trapping irrigation water.

The extent to which rough land—land having slopes in various directions with small high spots and hollows—may be leveled for irrigation will depend on both the cost of the operation and the depth of the soil. Heavy leveling requiring cuts of a few feet may be justified where the soil is exceptionally deep and high-priced water is to be used for high-valued crops. At the other extreme, some soils are so shallow and their subsoils so infertile that little or no leveling can be profitably done. Land so shallow that it cannot be leveled without seriously affecting its productivity or so rough that excessively large quantities of soil must be shifted should not be included in surface-irrigation plans. If such land is otherwise productive, it may be profitably irrigated by sprinkling.

Effect of Soil and Subsoil. The ideal soil for irrigation is deep, fertile loam or sandy loam with good drainage. Many kinds of soil can be irrigated, but those of intermediate texture are better than either very sandy soil or dense, impervious clay. It is difficult to spread irrigation water over deep sand and loose gravelly soil without overirrigating the portions of the field next to the head ditch. Overhead irrigation (sprinkling) may overcome such difficulties, but it is generally expensive and does not avoid the difficulty due to the small water-holding capacity of such soils.

"Tight," or dense, clays are difficult to irrigate because of the slow rate at which they absorb water. The time required for getting proper penetration of water into these impervious soils calls for extra labor in irrigating and, in extreme cases, may result in injury to the crop by scalding while the water is being held on the surface. Danger of scalding may be decreased by providing surface drainage and preventing any standing water from coming into contact with the plants.

Spongy soil of medium texture and high water-holding

capacity is especially favored because it permits easy application of water and generally gives good yields. High productivity is important, since farming under irrigation is relatively expensive.

Alkali. In dry regions, the problem of "alkali" must always be considered. In some localities, much of the land contains excessive amounts of these water-soluble salts—enough to reduce yields or even prevent the growth of crops altogether. Since many factors affect alkali damage, it is difficult to give definite figures as to the maximum quantity of salts in soil or water that will permit reasonable crop production. With an ample supply of good water and well-drained soil, however, all but the worst types of "black" alkali (sodium carbonate) can be leached out.

Source of Irrigation Water, Supply, and Public Control. Irrigation water in the Western states comes largely from snow and rain in the mountainous areas. About 80 per cent of the water is derived from surface streams, and 10 per cent from ground-water sources.

In practical irrigation operations, many storage reservoirs must be provided because so many streams fall to such low stages in summer that farming would be extremely hazardous if it were necessary to depend on direct diversion from these streams. Unfortunately, storage capacities in many reservoirs have been seriously depleted by intake of silt produced by soil erosion. It is becoming generally recognized that continued usefulness of many of the great irrigation projects will depend on speedy and effective reduction of erosion on the watersheds above the reservoirs.

Since there is not enough water to supply all that is needed to farm all of the better irrigable lands in those areas where agriculture is primarily dependent on irrigation, the states have

been forced to adopt laws governing appropriation and use of water. Stream waters have been widely declared to be public property in Western United States. Individual water users do not obtain actual title to such water, but they are granted the right, by the states, to take out specified amounts for beneficial use. These rights usually are granted on the basis of priority in time of application and proof of beneficial use. Such rights unfortunately continue to be jealously guarded, even though mere ownership of a water right does not everywhere entitle an individual to have delivered at his head gate any more water than he is able to use beneficially.

Considerably less progress has been made in establishing public control over the use of ground-water supplies.

Efficient Use of Irrigation Water. A permanent agriculture can be assured only through proper use of both land and water. The improper use of water has, in a relatively short time, impoverished much irrigated land and made a considerable area essentially useless. Every acre of an irrigation project that goes out of production because of improper use of either land or water adds a burden to the remaining productive area by compelling this area to pay all operation and maintenance costs of the project.

Origin of Wasteful Methods. In the beginning of irrigation farming in the United States, there was little or no knowledge as to how much water was required to produce a crop or how the water should be applied. Little thought was given to the matter of using water economically, since the supply usually was more than ample. Excessive quantities were often diverted from the streams into ditches that were not constructed to prevent large water losses by seepage. Generally, water was wastefully applied to the land. Soil erosion and some difficult drainage problems resulted. In numerous localities, more crops were

lost because of excessive water use rather than from any shortage of irrigation water.

Increased population, with the accompanying increased demand for water, has brought about some improvement but not nearly enough. Extension of old irrigation projects and development of new ones have focused more attention on these difficulties. State officials responsible for the administration of water supplies have made considerable progress in getting water users to repair and maintain their irrigation systems. There still are, however, thousands of irrigators who need to know more about the water requirements of their crops, more about the capabilities of their lands, and more about adjustments that need to be made in their irrigation systems. On thousands of farms and ranches, there is need for repairs on ditches, dams, diversions, and distributing systems as well as improvement in methods of irrigating.

Immediate Needs. Of the irrigated area in the United States, it has been estimated that 11,700,000 acres—more than half of the total irrigated area—are in need of supplemental water. Moreover, it appears that losses of water in distribution canals average nearly 30 per cent of the amount turned into the canals.

Farmers today, more than at any previous time, are learning the value of local group organizations in helping solve their irrigation problems. The Soil Conservation Service has taken a prominent part in assisting farmers with the installation of improved irrigation structures, repair of old installations, and improvement of irrigation practices. This has been accomplished mainly through cooperation with soil conservation districts.

Distribution on the Farm. The skill with which a farmer applies water to his crops is one of the most important factors influencing yields. No matter how expert he may be, he cannot

efficiently irrigate an inadequately leveled field or one where the water-distribution system has been improperly laid out. Where steep slopes are irrigated, extra caution is required for proper control of water in order to avoid excessive erosion. Too many farmers irrigating lands in need of leveling are wasting water and labor and are getting low yields.

The water-distribution system of a farm includes the ditches, pipes, flumes, and other devices necessary for conveying irrigation water from its point of delivery on the farm to the various fields, pastures, and meadows. A contour map of the farm is usually necessary to determine the best location of lateral ditches, field ditches, field boundaries, direction of border strips, and the like. Farm laterals must be located so that water can be efficiently delivered through a system of sublaterals and field ditches to the highest elevations on the land to be irrigated, with each lateral serving the greatest possible area consistent with efficiency. Laterals and ditches must be designed to provide the most economical cross section, with nonerosive gradients, consistent with the heads of water used and in conformity with reasonable ease of maintenance. Where laterals go through excessively porous soil, it may be necessary to provide some type of lining or to use pipes or flumes to prevent excessive seepage losses. On steep land, it is often desirable to locate the laterals along field divisions and property lines to facilitate operation and maintenance. Meter gates, weirs, Parshall flumes, or other measuring devices should be installed for each farm distribution system in order to eliminate guessing as to the amount of water used.

Head ditches should be located at the higher ends of the fields, with a sufficient number of turnout structures to provide for adequate control and distribution of water to the fields. In the case of long fields, it is often desirable to use additional head

ditches so that the length of run of water over the land will be such that a fairly uniform penetration into the soil can be obtained. Additional ditches may also be used to collect any excess water from the upper parts of fields for redistribution at lower levels.

Field ditches that require annual replacement should be located so that a minimum number of simple water-control structures, such as canvas dams, portable weirs, and pipes, will suffice for applying water to crops. Field ditches for *flood irrigation* of alfalfa and grain, where the topography is uneven, should be laid out as closely along the contour as practicable, and the spacing between ditches should be sufficiently close together to allow uniform distribution of the water over as much of the area as may be practicable, generally with short runs. *Furrow irrigation* under similar conditions should also follow grades not far off the contour (1, 2, or 3 per cent grades, generally, depending on soil conditions), with provisions for effective control over the quantity of water entering each furrow through the use of lath boxes, spiles, or tubing used as outlets in the supply ditches (Figs. 103, 104, 105, and 106).

The importance of balancing the cropping system to achieve the fullest use of the available water supply should be emphasized. Crop rotations should be planned not only to maintain soil fertility but to secure a balance between high and low water-requirement crops.

Crop Requirements of Irrigation Water. The amount of irrigation water needed to produce a crop is that required for transpiration plus evaporation, percolation, and runoff. Under any specific site condition, the *consumptive use* of water per unit of crop yield is quite definitely fixed; and if only that amount of water is used, the efficiency of irrigating would be 100 per cent. This, of course, could be impracticable to achieve under field conditions. It probably can be more closely ap-

proached by sprinkling than by any other method of application.

The wide range in consumptive use of irrigation water as between different localities is due largely to climatic variations,

Fig. 103—Serious erosion caused by irrigating on steep slope without proper water control. Riverton, Wyo.

especially in the amount of heat affecting a field, and resultant transpiration and evaporation from the fields during the growing season.

Predeterminations of the water requirements for an irrigation project or farm are usually worked out as averages based on the cropping systems, climate, soil, topography, and appraised ability of the farmer to use water efficiently. In the practical sense, there is no such thing as a rigidly fixed water requirement for a tract of land. Irrigation requirements vary with such chang-

ing factors as season, soil condition, and efficiency in application.

Frequency of irrigation is dependent on the water requirement of a particular crop and the water-holding capacity of the soil. The amount of water required for each irrigation is there-

Fig. 104.—Taking water out of head ditch into field furrows by means of siphoning tubes; light-weight plastic material is used. Scottsbluff, Neb.

fore limited to the amount necessary to keep the supply of soil moisture as near practical field capacity, plus losses through percolation, runoff, and evaporation, as is consistent with good plant growth. The depth to which soil moisture should be replenished will vary with the crop. In deep, friable soils, the roots of alfalfa and sugar beets, for example, may extend to depths of 6 feet or more, picking up some moisture throughout this soil depth if any is present. Most of the roots of such crops as pasture grasses usually do not extend to depths of more than about 18 inches; and for these, no great benefit is likely to be

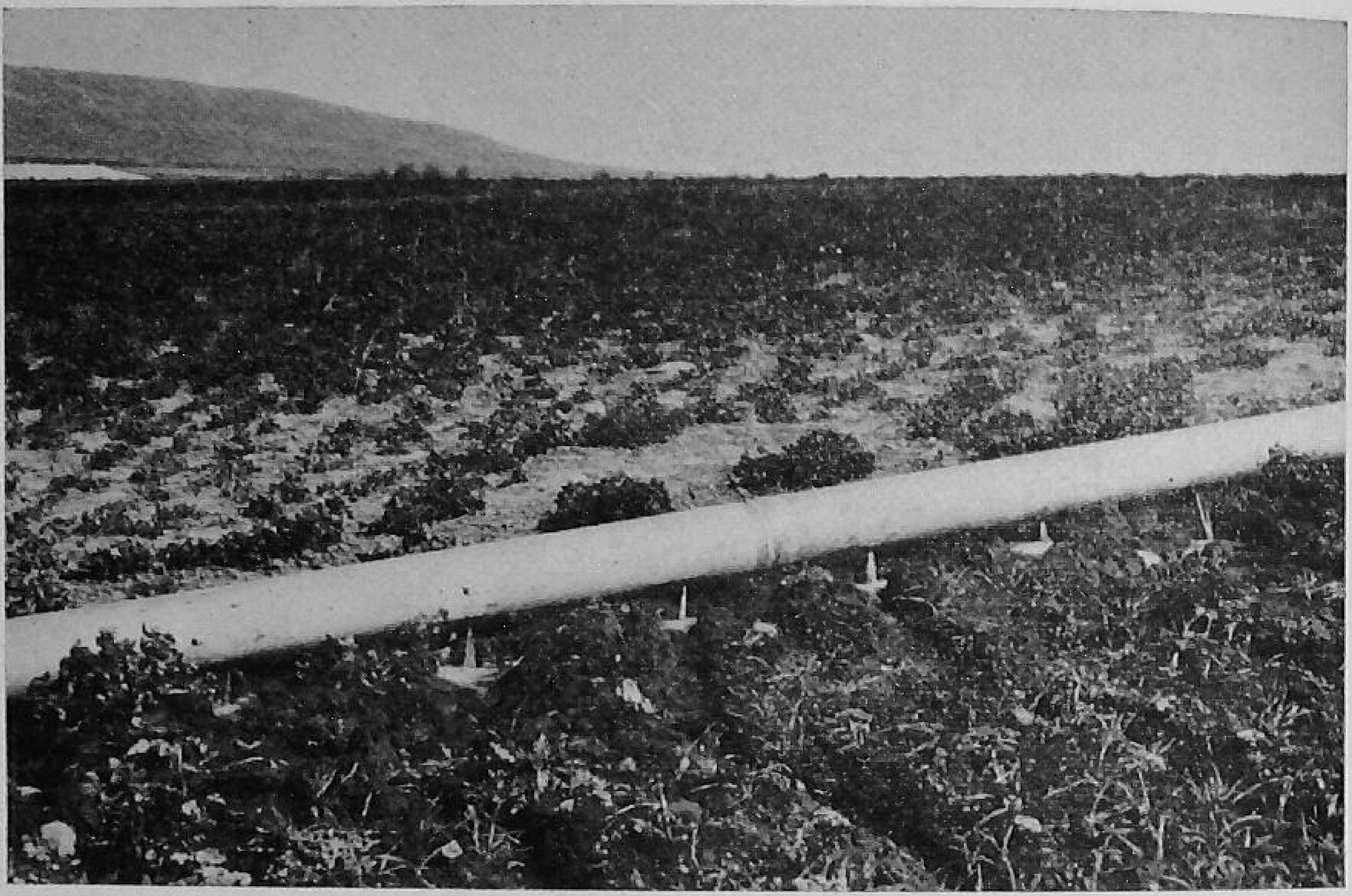

Fig. 105.—Portable pipe with flow-control gates is used quite successfully in irrigating on uneven ground. Kittitas County, Washington.

Fig. 106.—Strawberries irrigated on near-contour grades. California. (Work by Soil Conservation Service.)

derived from irrigation water penetrating below depths of about 2 feet.

Deep-rooting crops use some water from depths of 4 to 6 feet or even more under favorable circumstances, but the bulk is taken from the top 3 feet of the soil profile, as illustrated in the following tabulation of data from the Scottsbluff, Neb., Field Station:

TABLE 12. WATER CONSUMPTION BY FOUR IMPORTANT CROPS FROM DIFFERENT DEPTHS THROUGH THE SOIL PROFILE, GROWN UNDER IRRIGATION AT SCOTTSBLUFF, NEB.

Depth, ft.	Percentage of moisture taken up by crop			
	Oats	Potatoes	Alfalfa	Sugar beets
0–1	64	57	47	62
1–2	16	23	15	19
2–3	12	13	15	12
3–4	8	7	12	7
4–5	....	....	8	
5–6	....	....	3	

Although these percentages would, of course, not be duplicated in all soils, they serve as indications of what may generally be expected, approximately, under normal irrigation practice; that is, the upper 2 to 4 feet of the soil profile is the important water-supplying zone for crops. Some farmers irrigate heavily either late in the fall or early in the spring in order to wet the subsoil deeply, following with irrigations gauged to penetrate to depths of 4 feet for alfalfa, 3 feet for ordinary field crops, and about 18 inches for pastures.

After it is turned off at the head ditch, some movement of water takes place in the soil. This is least in light-textured soils having no impervious compact, hardpan, or claypan sublayers.

In soils having sublayers of this nature, a "perched" water table (temporary) is likely to develop just above any such relatively impervious horizon, this serving to slow the rate of percolation. In open, pervious soils, irrigation may be continued until the necessary penetration has been obtained; but where there are obstructive sublayers, depth of penetration 24 to 36 hours after irrigation is highly important. In other words, a farmer must know the usable water capacity of his land and irrigate accordingly.

It is generally unsafe to wait until all available moisture within reach of the plant roots is gone before irrigating. Some waste of water through deep percolation, surface runoff, and loss in the farm-distribution system is unavoidable. Thus a single application may reasonably be expected to vary between 3 and 10 acre-inches per acre, depending on losses to be expected under a particular set of conditions and circumstances. Under most circumstances, however, enough moisture will be held over in the soil at irrigation time for an application of not to exceed 5 or 6 acre-inches per acre to suffice.

Frequency of irrigation will be influenced both by the crop and by the soil condition. With a crop like alfalfa, which grows continuously throughout the irrigation season, the principal factor is the water-holding capacity of the soil. No one method of water delivery will be equally suitable for all lands, so that, if the right amounts are to be used, the size of the irrigating heads and the intervals between water deliveries must be reasonably adjusted to soil, crop, and topography.

Relation to Erosion. On steep land, it is important that the head of water be held down sufficiently to allow distribution through enough *corrugations* (distributary furrows) to prevent soil erosion. On the other hand, the use of excessively small heads is wasteful because of such difficulties as high transmission losses and slow distribution. Where clean-tilled crops are

grown, heads of more than 1 cubic foot per second can seldom be handled on erodible land without soil washing. A somewhat larger head can be used on the same slope where it is kept in grass or alfalfa, particularly where flumes, pipes, or spiles are used for controlling the flow to the corrugations or furrows.

On light-textured and shallow soils of gentle slope and flat surface, flooding between *border strips* of moderate length with large heads of water has shown good results. Heads of 3 to 5 cubic feet per second have frequently proved necessary under such conditions. On medium-textured soils—loams and heavy sandy loams—of moderate slope, the requirements for water deliveries are less exacting. Considerably larger irrigating heads than for steep slopes can be used. Heads as high as 2 to 3 cubic feet per second will generally be applicable.

Under the border-strip method of irrigation, the land is laid out in strips separated by earth borders or ridges that serve to control and guide the water. These strips are level across the slope, but they have a gentle slope from the head ditch to the lower side of the strip.

Land Leveling. Satisfactory flow of irrigation water calls for a continuous slope of uniform surface configuration within the length of any run. These conditions have a marked influence on efficient use of irrigation water—use that avoids soil erosion, waterlogging, and excessive time required for application. Where the land is not properly leveled, part of the field will be overirrigated or underirrigated, causing crop losses, waste of water, and often seepage damage to lower lying land.

In leveling, care should be taken that only a minimum of topsoil is moved. If a high spot cannot be irrigated, however, it generally should be cut down in spite of any lowering of its productivity. Where considerable topsoil must be removed, heavy applications of barnyard manure and the plowing under of green-manure crops are usually helpful in improving crop-

ping conditions. If the soil is shallow, it frequently is advantageous to sacrifice cheapness and convenience to the use of a method that will leave the soil undisturbed.

Surveys for leveling operations vary with the individual field. With a contour map, the direction, location, and quantity of soil movement can be determined. The approximate balancing of cut and fill by contour areas or by cross sections is necessary to keep the cost to a minimum. If the land slope is less than 3 per cent, contour intervals of not over 1 foot are desirable. Minute refinements in balancing cut and fill, however, are not justified in most instances. Usually after the approximate quantities of earth to be moved and the direction of movement and location of cuts and fills have been determined, a few stakes can be set marking the high spots with the approximate cut and the low spots with the amount of fill. Satisfactory checking for uniformity of slope following rough leveling can be easily done with a hand level, after a little practice.

If the soil is dry or if heavy fills are made, the use of a roller or cultipacker is desirable to hasten settlement. Very seldom is it possible to complete a leveling job until after the first crop, which is ordinarily a cereal. The spots requiring additional leveling can be determined during the irrigation of this first crop. Also after the first crop, the fills will have settled. If rough leveling is carefully done, final leveling can usually be accomplished with simpler leveling devices. Heavy leveling requires such implements as bulldozers, carryall scrapers, and fresnoes. Light leveling, which is slightly more than "floating" (dragging down the surface), can be done with land planes, motor patrol graders, and similar implements having a long wheel base (Fig. 107).

Overhead Irrigation. Under certain conditions, irrigation can be accomplished best by sprinkling. Sprinkler systems may be classified as permanent, semipermanent, or portable, as high- or

low-pressure, and as straight-line or sprinkler-head. The sprinkler-head group may be subdivided between stationary and rotating heads. Almost any combination of these features may be found in operation.

Fig. 107.—Land leveling and smoothing ("floating") to ensure even distribution of irrigation water. Shannon, South Dakota. (Work by Soil Conservation Service.)

The permanent systems involve a large investment in distribution pipes and sprinklers and for that reason are, in general, confined to such intensive farm units as truck gardens, nurseries, and orchards. The cost of labor for the application of water is very small with these systems and partly compensates for the high initial investment. Portable systems, on the contrary, require a much smaller investment, but a considerable amount of labor is needed to move the equipment. Since the use of sprinklers involves high costs for the necessary piping and other equipment, for the power required to provide pres-

sure, and for labor, it may frequently not be advisable to go too readily into large sprinkler operations where equally satisfactory results can be secured by surface methods.

Conditions that are likely to hinder or prevent successful surface irrigation and make the sprinkler method desirable are (1) land too rough and soil too shallow to permit a minimum of leveling, (2) soil so porous that water cannot be applied by surface methods without serious loss, (3) a stream of irrigation water so small that surface methods of application would be too slow, (4) steep slopes with either highly erodible or relatively impermeable soils, and (5) special labor or management conditions on the farm that make the more or less automatic nature of sprinkler irrigation particularly advantageous.

The requirements for a successful sprinkler-irrigation system are uniform distribution of water at the proper rate and relatively low total cost of irrigation. Each of the systems of sprinkler irrigation has advantages and disadvantages, and the proper choice will depend on the conditions to be met on each farm.

Questions

1. What is irrigation farming? In what part of the country is it most extensively used? What is the area of irrigated land in the United States?

2. What are the principal factors governing selection of an irrigated farm? Describe an ideal field for irrigation.

3. What is the relation of alkali to irrigation?

4. What is the principal source of irrigation water? Why is it necessary to store up water for irrigation?

5. Give reasons for and some of the principal methods used in public control of irrigation water.

6. Give some of the principal causes for inefficient use of irrigation water.

7. What are the most outstanding immediate needs with respect to efficiency in irrigation?

8. What is the principal basis of sound farm distribution of irrigation water? Describe some of the better methods.
9. Why should a farmer install measuring devices for determining the water used on his land?
10. What is the significance of short runs of irrigation water?
11. What is flood irrigation? Furrow irrigation?
12. How much irrigation water is required to produce a crop in localities where rainfall is of no importance?
13. How often should crops be irrigated?
14. How deep do crops go into the soil for irrigation water?
15. After turning off water at the head ditch, what happens to the water already distributed?
16. Explain some of the erosion hazards of irrigation.
17. What is the border system of irrigation?
18. What is the purpose of land leveling? What guiding principle should be considered in leveling operations?
19. What is overhead irrigation? What precautions should be considered under this system?

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CHAPTER 22

The Place of Trees and Shrubs in Soil and Water Conservation

PRESENTING:

Effect of Forests on Soil Erosion
Forestry in Soil and Water Conservation
Windbreaks and Shelter Belts
Tree Planting
Management of Farm Woodlands
Farmer Interest in Tree Planting
Place of Trees in Soil Conservation

Of the 630 million acres rated as forest land in the United States, about 137 million acres have been classed as farm woodlands (1940 census). These farm woods are composed of many thousands of individual patches and some relatively large tracts. They comprise more than a fifth of the entire forested area of the United States and represent 14 per cent of the total farm land. In the New England states, 40 per cent of the farms (an average of 38 acres per farm) is wooded. In the Southern states, about one-third of each farm is wooded.

Efforts are being made to protect our public forests from fire and overgrazing of the included grasslands. Properly managed forests reduce the hazard of erosion and contribute to the maintenance of stream flow, especially along headwater streams. Thus, from the standpoint of public welfare, it is important that much critical, mountainous headwater country be kept in forest.

The 250 million acres of privately owned forest, other than farm woodlands, include most of what is commonly called commercial forests. Parts of these woodlands also have an important relation to the stabilization of stream flow, although the benefits are of relatively less importance than in the case of public forests because more of the land occupies lower, less rugged country.

Woodland too often has not been looked upon as a productive part of the farm enterprise; income derived from it has been considered incidental. Any consideration of the fact that from 20 to 40 per cent of most farms in Eastern United States is covered with woods of some sort should be convincing evidence that this large area should be made more productive than it has been in our agricultural past.

Effect of Forests on Soil Erosion. The capacity of trees to reclothe and protect worn-out land is proved by the forests that have grown up in many parts of the country on abandoned cropland (Fig. 108). Throughout many of the Eastern states, for example, old stone fences can be found in the midst of newly grown forests. These mark the boundaries of formerly cultivated fields. The ridges of corn rows still can be distinguished in the dense second (or later) growth covering some of these old fields. Even wild apple trees, descendants or remnants of farmers' orchards, sometimes are stumbled upon as one travels through such woodlands. Similar evidences of former cultivation can be seen in the pine forests now growing in old fields of the Cotton Belt, where before cotton there were hardwoods and pine.

In a good growth of forest, the branches of trees frequently are close enough to touch and form a closed canopy; small trees, shrubs, and other forms of lesser vegetation often make up a more or less dense undergrowth. The leaves, twigs, branches, and stems of such a forest expose innumerable little surfaces,

aggregating, under good conditions, an area several times greater than that of the ground beneath. This loosely thatched roof, often 100 feet or more in thickness, is the first line of protection against soil erosion and excessive runoff. Driving rains

Fig. 108.—Good forests have grown to maturity on land formerly cropped and abandoned because of soil impoverishment, as on this Georgia hillside. (Photograph by U. S. Forest Service.)

beat upon this roof; a large proportion of the raindrops spatter into mist and spray. Another part of the precipitation slips gently down stems and tree trunks or drips intermittently and harmlessly to the ground. As much as $\frac{1}{2}$ inch of rainfall may be completely intercepted by this intervening thatch of vegetation. Most of this intercepted water is lost by evaporation and so never reaches the ground.

The main forest bulwarks against erosion and runoff, however, are still lower down. Covering the forest floor is a blanket of woods litter (dead debris)—a mass of leaves, twigs,

and fragments of bark in various stages of disintegration (Fig. 109). This blanket of litter performs a double function: (1) absorption by the litter of part of the rainfall and (2) establishment of a condition favoring the infiltration (intake by the soil) of a much larger part of the rainfall by keeping the water

Fig. 109.—The principal forest bulwark against erosion is the litter and mold covering the ground.

clear and ready to filter freely into the soil beneath. Thus this all-important accumulated blanket of dead vegetative material exerts a powerful beneficial influence on the soil in several ways, for one thing making it much more permeable to water than the bared soil would be (Fig. 110). The surface of the soil is kept moist and absorbent, often even in winter when exposed soil is deeply frozen, less absorbent, and of low-intake capacity. Also, the litter and humus (decomposed vegetable matter) form the principal habitat for a vast population of organisms important to soil building and conditioning. From the standpoint

of soil protection and water intake, this debris covering of the forest floor is the most effective element of the forest complex. Here is the gateway to increased storage of rainwater in the soil and underground channels. Its function, as pointed out above,

Fig. 110.—Virgin forest soils are generally characterized by highly permeable, mellow, or granular topsoil. Often in dry weather, when neighboring cultivated land is of almost stonelike hardness, forested soil is moist and soft enough to dig into with the bare hands. (Photograph by U. S. Forest Service.)

is to keep rainwater clear and so keep it moving downward into the soil. Muddy water, such as gathers on bare ground, clogs the soil-entrance channels, as previously pointed out, with soil filtered out of the muddy suspension, and this, of course, results in slowing infiltration and turning rainfall from beneficial percolation to harmful runoff and erosion.

Forestry in Soil and Water Conservation. In any system of sound land use, it is essential that excessively steep slopes, such

as usually prevail about the headwaters of numerous streams, be kept in some form of dense cover, preferably forest, grass, or legumes. Trees make the most adaptable protective cover for vast areas of mountain and hill country, where it is not easy to establish and maintain an adequate cover of grass. Grass is the proper form of vegetation to use in those areas which are not climatically suited to rapid tree growth but are well suited to grass. Shrubs and combinations of trees and shrubs have highly important places for special conditions in the control of runoff and erosion.

Windbreaks and Shelter Belts. Under conditions of low rainfall, a number of hardy trees and shrubs have proved successful in *windbreak* (shelter belt) plantings. Such plantings are valuable not only from the standpoint of their utility but for their effect in making farm homes more livable and comfortable for both men and animals in times of climatic extremes (Figs. 111 and 112). Tree windbreaks slow up and deflect the wind near the ground, temper hot winds, and moderate the ill effects of cold winds. They also check local dust storms that would otherwise sweep topsoil from the fields.

When the velocity of winds is checked, evaporation of soil moisture is reduced and the water thus saved is made available for production of crops. In a similar way, windbreaks protect farm homesites, feed lots, and gardens, thus saving fuel and feed and often increasing the productiveness of gardens. The effectiveness of trees as windbreaks depends mainly on the compactness of the barrier and its height. Experiments indicate some effect at distances up to as much as fifty times the general average height of the trees, but ten to twenty times the height (Graph 14) is usually considered the practical limit of effect. Farmers who own tree windbreaks in the Great Plains area often are enthusiastic about benefits in the form of increased crop yields and reduced expenses for fuel and feed.

Tree Planting. Successful planting of trees, even on a small scale, is seldom a simple matter. The first, and probably most important, step is the selection of adaptable trees for particular sites. Correct determination of the species, size of planting

Fig. 111.—End view of a Nebraska windbreak. These shelters of hardy trees and shrubs protect strips of adjacent land from soil blowing, protect livestock, and make homes in treeless areas more livable.

stock, and cultural practices to be used is basic to successful afforestation. At first, it sometimes is necessary to plant species that may not ultimately occupy the areas to be protected. Unless cultural treatment promises to overcome or quickly improve the adverse conditions, a hardier species better suited to the prevailing conditions should be selected. Such local factors as elevation, exposure, quantity and distribution of rainfall, texture of the soils, drainage conditions, and intensity and direction of the winds must be given similar consideration. A hilltop of

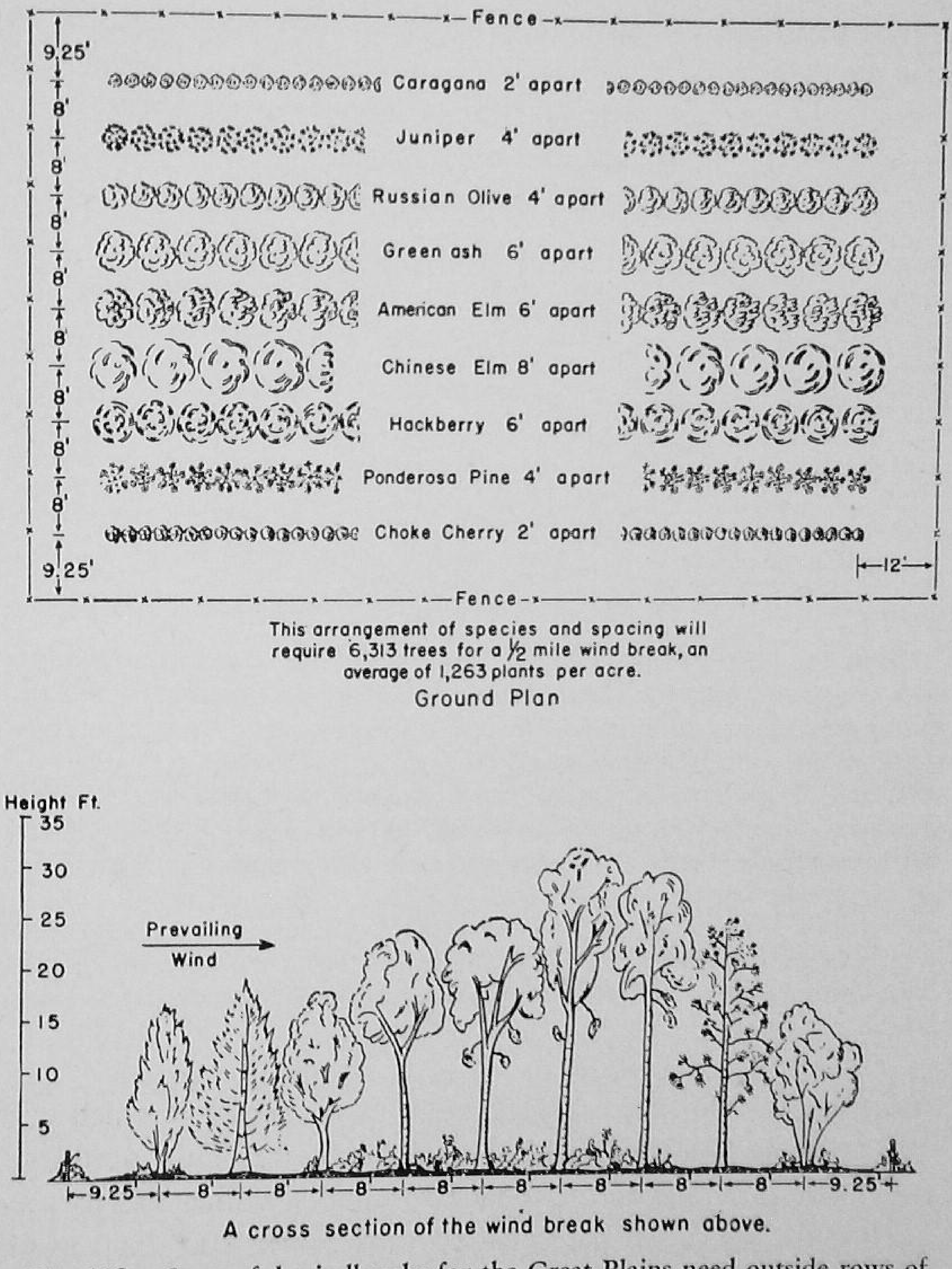
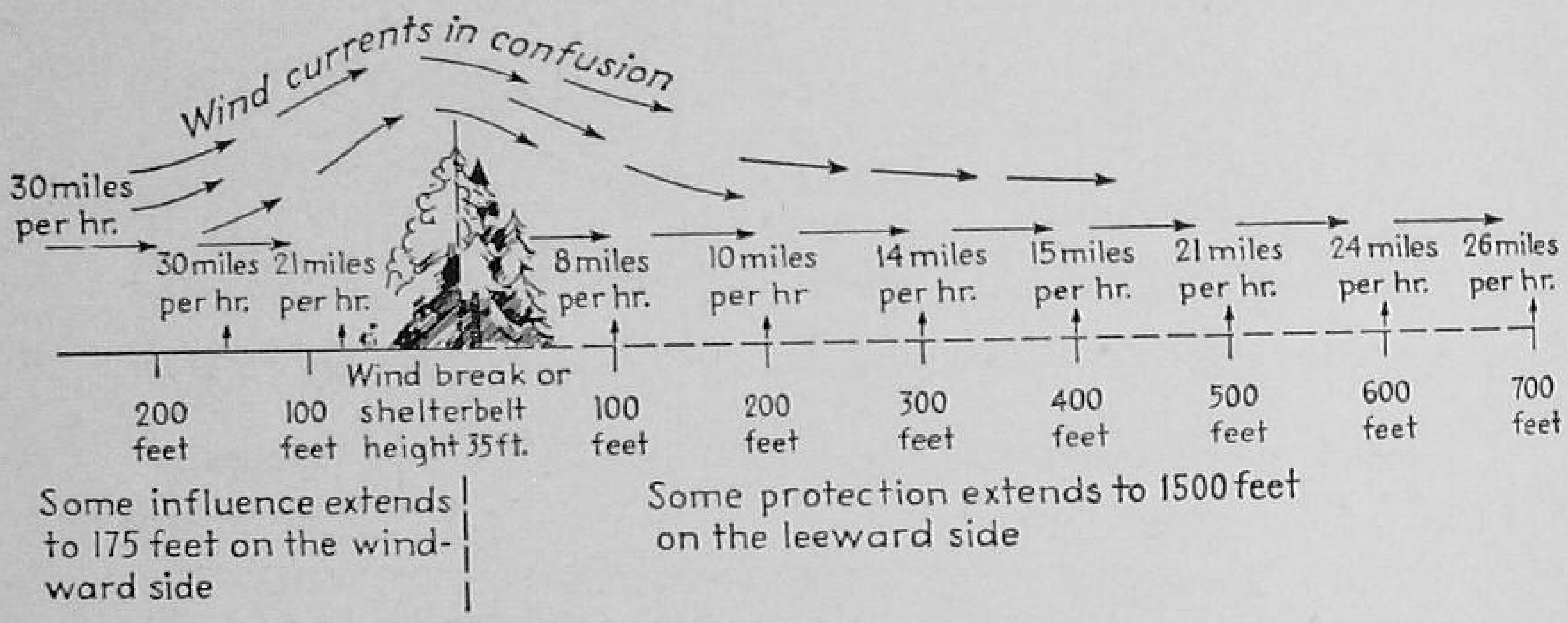


Fig. 112.—Successful windbreaks for the Great Plains need outside rows of shrubs to cut off ground wind and taller trees in the center to deflect above-ground wind.

dry, shallow soil over rock is no place for trees accustomed to moist lowlands.

Not only have the original trees of severely eroded areas been destroyed, but the shrubs and other plants as well. The problem of proper reforestation, therefore, may involve reestablish-



Graph 14.—Tree plantings are used by farmers and landowners to protect their homes and livestock from cold and hot winds and to assist in the control of erosion on cultivated fields caused by high winds. Farm homes protected on the north by a good windbreak such as is illustrated in this drawing will save 25 per cent of the fuel requirements for the winter. When a windbreak protects both on the north and the west, a saving of 34 per cent can be expected. Cattle and horses that have the advantage of a protection of windbreaks require less feed and gain in weight more rapidly. Fields protected by 5- to 10-row strips of trees (called "shelterbelts") help to control wind erosion, contribute substantially to the saving of moisture, and protect crops from damage by high winds. (Based on data from the U. S. Forest Service.)

ment of the entire flora, beginning with those plants which will lay down an essential ground cover of litter. This would require the planting of those pioneer species which aid in preparing the land for a higher type of forest, such as certain conifers to precede hardwoods.

For example, it has been found that hard maple will not make satisfactory growth when planted on old fields alone or associated with other hardwoods. If, however, maple is planted

in alternate rows with pine trees, the latter tend to improve the soil conditions so that the resulting growth of the maple is satisfactory.

Every climatic zone has in its flora at least one species suitable as temporary or preliminary vegetative cover, even on poor land. Among the shrubs, the number of species is generally larger than among trees. Often the most adaptable species for conditioning the site have little commercial value.

It is frequently possible, as already indicated, to overcome adverse site conditions, as by proper preparation of the soil. In places where erosion has so impoverished the land that only worthless kinds of vegetation will grow, the landowner is neither satisfied to plant species without economic value nor willing to wait on the slow process of natural rehabilitation. It therefore becomes necessary to prepare the land for immediate planting by cultivation, fertilization, mulching, or other means.

Hardwoods or broadleaf trees generally must have either a better site or more careful preparation for planting and better care afterwards than coniferous trees.

The native pines of the South, for example, will grow fairly well generally on severely eroded land with little or no preparation of the soil and without subsequent care other than protection from fire and grazing. If black locust is desired for fence posts, however, preparation of the soil is generally needed, and even cultivation and fertilization of the trees during the first 2 or 3 years after planting. Good soil gives the best results.

As a rule, the more adverse the site the greater is the need for preparation for planting and frequently for attention after planting, especially with broadleaf trees. Adaptable trees, for example, can be grown in the more favorable situations of low-rainfall areas, such as the Great Plains, but real success depends (1) on careful preparation of the land to be planted and later (2) on cultivation. In this region, the land generally should be

plowed and contour listed or basin listed and carefully tilled to prevent loss of soil moisture by weed growth for a year in advance of planting. After planting, both trees and shrubs may require cultivation or weeding for several years or until the growth becomes too dense for the use of cultural implements.

On areas of raw erosion-exposed subsoil, it frequently is impossible to get trees or shrubs started satisfactorily without covering the surface with a mulch of such vegetative material as straw, forest litter, rotted hay, or barnyard manure. Where soil and topographic conditions permit, plowing under a legume cover crop is one of the best methods of soil preparation. On thin land, even the planting of pines is a good first-step measure of soil preparation for hardwoods. The mat of needles accumulating when fire is kept out gradually conditions the soil for the broadleaf trees. In the East, such hardwoods as oak, maple, beech, hickory, dogwood, and gum will gradually intermix with or replace the pines.

Preparation for Gully Planting. Preparation for planting gullies frequently requires the building of temporary dams in the bottoms to catch enough silt and moisture to get the trees started. Bank sloping is often advisable along steep-sided gullies; and in many instances, water must be diverted from the heads before any success can be attained with planting in the gully itself. Turning aside water at the head of a gully often provides enough stability within the ravine to proceed with planting.

Conservation Nurseries. The Soil Conservation Service maintains a series of nurseries throughout the United States, with a productive capacity of 150 to 250 million trees and shrubs. These seedlings are used in connection with the national program of soil and water conservation in which the Service is engaged. Additional millions of trees are being produced in Forest Service and state nurseries and in commercial nurseries.

The conservation nurseries also produce seed supplies of "domesticated" native and introduced grasses and legumes where such seed have not yet found their way into commercial establishments.

The experience of the Soil Conservation Service has shown that much more farm land, both cultivated and uncultivated (idle), should be restored to forest than previously had been suspected. On the basis of detailed farm surveys made in connection with the erosion control program, it is estimated that some 40 million acres of this land now cropped should be planted to trees, shrubs, grass, and other adaptable plants in order to protect it from erosion and conserve rainfall; produce wood supplies, hay, and grazing; benefit wildlife; etc. If this work is to be carried out, about two billion trees and shrubs will be required annually over a period of 25 years.

Because of the risks in handling planting stock—in taking the seedlings from the soil, grading, heeling in, and transportation—foresters agree that better results are had where the seedlings are obtained near the planting site. This reduces handling and danger of losses from overheating, drying out, and spread of disease. Farmers who can go into near-by woods and collect acorns or nuts or wild planting stock for immediate use on their lands will be able to meet part or all of their needs.

Planting and Maintenance. From the nursery or heel-in bed planting site to the actual setting out of the seedlings, every care must be taken to move the work along according to a well-planned schedule, step by step (Fig. 113), until the trees are in the ground. The difference between good planting and poor planting is often the difference between the success or failure of the operation. Large plantings, therefore, require the assembling of labor, the training of men, and adequate arrangements for transportation.

The time of planting is probably one of the most, if not the most, important factors in the survival of trees. Throughout most of the United States, the planting season is limited to a few weeks in the spring. It begins as soon as the frost is out of

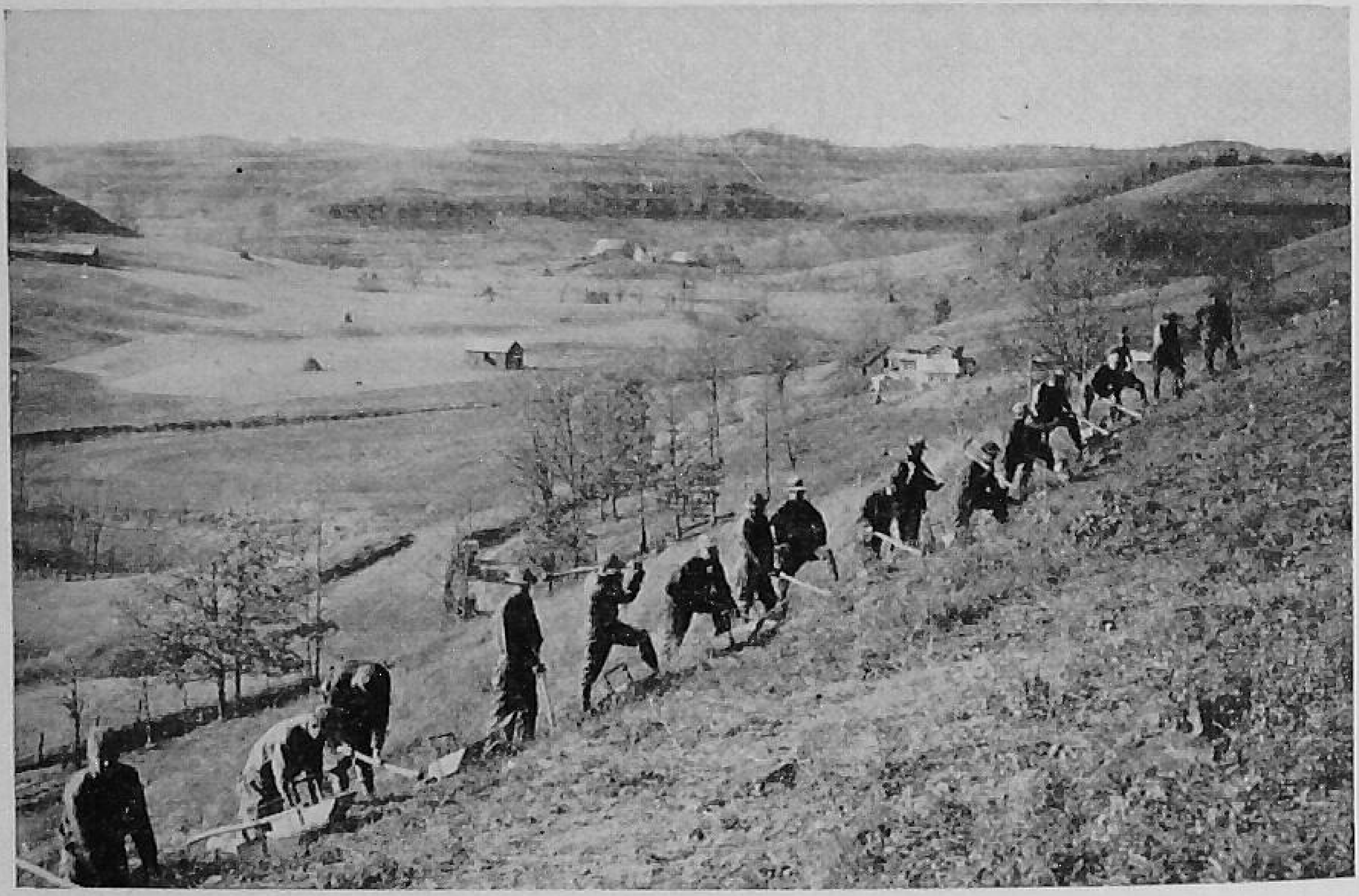


Fig. 113.—Men must be trained to plant trees properly. The difference between good planting is often the difference between success and failure. West Virginia.

The Soil Conservation Service planted, with Civilian Conservation Corps labor, 257 million trees and shrubs during the period of January, 1935 to June 30, 1940.

the ground and danger of freezing past. The sooner the trees are in the ground under these favorable conditions the better the chance for success.

The spacing of trees ranges from 1-foot intervals (in both directions), as in the planting of willows along stream banks, to as much as 10 to 12 feet where natural growth may be expected to fill the gaps. Usually about 6 by 6 feet is considered

standard spacing for forest-tree planting. Under conditions where the establishment of a quick cover is needed, the spacing frequently is 4 by 4 feet; and with shrubs, 2 by 2 feet. A certain amount of site preparation may be done at the time when trees are planted.

After planting, protection from fire and grazing must be provided. The safeguarding of large forest plantings from fire may require patrol and the construction of fire lanes during dry seasons. Protection from stock may demand either herding of the animals or their exclusion by fencing. Occasionally, artificial shading is necessary, as under the adverse conditions of semiarid climate or where the trees are of unusual value.

After the first year, some replanting is usually necessary because of the failure of some of the seedlings. Experience of the Soil Conservation Service indicates that, on the average, failure of survival may be expected to require replanting about 15 per cent of the original number of trees set out.

Thinning of stands is a cultural operation that comes considerably later than other maintenance measures. Ordinarily, it is not considered practicable to thin stands until the trees are pole size or large enough to yield some fuel and pulp or fence posts. The need for thinning in young stands is usually indicated by a general slowing up of the rate of growth, particularly in diameter. Growth can be determined readily by cutting a few trees to determine the relative width between the annual growth rings. If the distance between the outer rings is about the same as or greater than that between the inner rings, the tree is still maintaining good growth. If it is found that the width of the inner-ring spaces is narrower toward the bark, then growth is slowing down and the trees need more space.

It is sometimes necessary to remove the lower branches of growing trees in order that clear wood may be produced. Ordinarily, density of stand aids in natural pruning; but if the

lower branches persist and are not removed artificially, many valuable species will not yield a high-grade product. Only those more promising trees should be pruned—those which are growing fast have the best form. Ordinarily, not more than 150 crop trees per acre should be selected for pruning. Trees over 8 inches in diameter generally should not be pruned.

For best results in pruning, the branches should be removed with a saw operated as close to the trunk as possible. New wood grows over such a cut very rapidly, with the result that more clear wood is produced. The height of pruning should not exceed the length of clear wood desired. Pruning up to 16 to 20 feet will give one clear, high-grade log. The cost of such work must be justified by the increased income from logs of higher quality.

Management of Farm Woodlands. The greatest enemy of forests is fire. Fire destroys both the forest litter and young trees; it often kills even the larger trees. Frequently, even though trees are not killed, they are scarred and made more susceptible to insect attack and disease. The forest canopy is thinned, and the soil often exposed to erosion. Severe forest fires frequently destroy all the trees.

Continued grazing of farm woodland usually results in some degree of damage, often severe. A good fence to keep domestic animals out of the woods is one of the best forms of forest insurance. Since livestock browse young trees, both hardwoods and conifers, grazing not only injures or destroys young trees but frequently leads to injury or destruction of many of the large trees. Grazing of woodland tends to impair or destroy forest litter, and this, in turn, reduces infiltration, speeds up runoff, and lowers the productivity of the forest. Investigations by the Ohio Agricultural Experiment Station show that for the sites studied, open pasture produces $2\frac{1}{2}$ times more grass and that its nutritive value is 20 to 60 per cent greater than woods

grass. Woodland grazing usually yields relatively poor returns in pounds of meat and at the same time damages the forest.

Grazing damage to woodlands is, of course, a matter of intensity of use. Controlled grazing of livestock in the Western coniferous forests and in the pine lands of the Southern Coastal Plains is generally recognized as acceptable practice. In such cases, management is possible so as to permit utilization of forage without material injury to the woodland.

One of the important phases of the forestry job in connection with control of erosion is to convince the farmer of the value of his farm woods. When farmers realize the value of protecting their woodlands from fire, grazing, and neglect, they usually set about the job of preventing abuse and building up the woods. Generally, they need some technical help; but once convinced of the benefits, they are likely to accomplish a good deal on their own initiative.

Value of Farm Woods. Millions of board feet of lumber are utilized every year in the construction and maintenance of farm buildings. The agricultural enterprise of the nation makes use of millions of posts annually in the maintenance of fences. Wood, the chief fuel on the farm, is used in nearly all parts of the country. Many other forest products are used: poles, stakes, braces, logs, fence rails, handles, wood for cooking, curing tobacco, and processing sirups, and wood for lumber, pulp, and cellulose.

Good farm woodlands create a favorable habitat for many kinds of wildlife. Burned or closely grazed woods offer little cover and almost no food for wildlife.

Where farm woodlands produce more than is required for the farm needs, the surplus often can be marketed to advantage. Many farms offer excellent opportunity for development of woodlands to produce wood materials for sale as cash crops. On numerous farms, properly managed woodland is producing

net annual returns in stumpage and labor of around $4 to $10 per acre.

By selective cutting, forests that are properly cared for generally can be maintained on a permanently productive or sustained-yield basis. Under modern practice, a variety of species and sizes of trees should be maintained. Farm needs for posts, poles, fuel, and rough lumber should be supplied first by cutting out defective, poorly formed, slow-growing trees and those species which make up more of the stand than is required in a desirable mixture. If the poorest trees are constantly selected for home use, cutting only mature trees of good quality for market, and every precaution is taken to hold the quantity removed equal to or less than the quantity grown in the same period, even a badly neglected woodland generally can be built up gradually to at least a fair condition of productivity. The growing stock in the woods must be built up in a way something like that of the stockman who improves his herd by selective removals and replacements. By cutting only those trees that are ripe for the market, together with the wood needed on the farm, the farmer can obtain an annual or periodic income. Cuttings at relatively short intervals are conducive to good forest growth.

In its cooperative work with farmers, the Soil Conservation Service follows a simple procedure of education and the application of practical woodland measures. Where needed, a stockproof fence is recommended. Applicable measures for protection against fire are provided, such as the establishment of fire lanes and the most advantageous system of disposing of slash. In severely eroded localities, it may be well to utilize the slash, or part of it, for gully-control purposes or for mulching raw subsoil areas as an aid to reestablishment of trees, shrubs, or other forms of vegetative cover.

Farmer Interest in Tree Planting. In order to arouse farmers' interest and action, practical foresters must work with them—plan and help with planting, fire protection, cutting, disposal of slash, etc. Furnishing technical advice on the ground has

Fig. 114.—Demonstration of selective cutting in a Pennsylvania farm woodlot. (Work by Soil Conservation Service.)

proved the most effective means for arousing interest and, in some localities, the only means of getting action (Fig. 114). Taking over the control of cutting on privately owned woodlands is probably not so likely to accomplish as much efficient forest management as would be obtained through the cooperative method used by the Soil Conservation Service in its work with soil conservation districts.

Unfortunately, an element of the pioneer farmer's philosophy that a piece of woods was a barrier in the way of farm progress still persists in some localities. Since agricultural practice has

long been governed by a "ground-line" philosophy that calls for the complete removal of natural vegetation about the ground surface and that relies for the next crop on natural seeding or reproduction from roots, it is not surprising to find that many farm woods consist of trees that have come from sprouts (coppice woods). Coppice woods are produced by clean cutting, just as a crop of asparagus springs from the roots, following previous cuttings. The difference is that the asparagus yields satisfactorily under the system whereas sprout trees generally are of unsatisfactory quality. Fortunately, in soil conservation work it has been possible to change this viewpoint along the lines indicated.

Place of Trees in Soil Conservation. The fundamental concept and policy of the Soil Conservation Service that, in so far as practicable and economically feasible, every acre of land must be treated in accordance with its need and adaptabilities has aided greatly in educating farmers with respect to the value of good forest and good grass and good crops of legumes for protecting highly erodible land. These gains having been made, it is proving a great deal easier to induce farmers to go ahead with good tree practice, good meadow practice, and good pasture practice. When the ugly scars of erosion are effaced with trees, shrubs, grass, and legumes, when excessive runoff from critical slopes is stopped, when wildlife comes back as the result of plantings of trees, shrubs, grasses, and legumes, most farmers feel compensated by these advantages alone. Subsequently, when products for sale begin to mature in the protected areas and better crops are produced on lower lying land protected by these plantings, it generally may be considered, according to the experience of the Service, that the average farmer is then definitely won over to a sound farm program of protective plantings of trees, shrubs, grasses, or other plants.

Where soil and water conservation is the goal, efficient achievement can be had, as previously pointed out, only by treating the land according to its needs and adaptability. Under that concept—and this is fundamental in the program of the Soil Conservation Service—trees represent just one of the many useful forms of vegetation that are available for getting the job done.

Questions

1. Describe present distribution of forests in United States.
2. What effect does the forest canopy have on rainfall? What is the principal function of forest litter? Windbreaks?
3. What important precautions must be observed in tree planting?
4. What is the best way to establish trees on exposed clay subsoil?
5. What are conservation nurseries?
6. When is the best time to plant trees?
7. Name one of the principal measures for sustained forest cutting.
8. What is the effect of grazing on woodlands?
9. Describe briefly the income value of farm woodlands.
10. How do trees fit into the national program of soil conservation?
11. What is coppice forest?
12. What is sustained forest production?

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List of Visual Aids

The following list of visual aids can be used to supplement some of the material in this book. These films and filmstrips can be secured from the producer or distributor listed with each title. (The addresses of these producers and distributors are given at the end of the bibliography.) In many cases these films can be secured from your local film library or local film distributor; also, many universities have large film libraries from which these films can be borrowed.

The running time (min), whether it is silent (si) or sound (sd), motion picture (MP) or filmstrip (FS) are listed with each title. All those not listed as color (C) are black and white. All of the motion pictures are 16mm; filmstrips are 35mm.

Each film has been listed only once in connection with the chapter to which it is most applicable. However, in many cases the film might be used advantageously in connection with other chapters.

Chapter 1—The Erosion Problem in the United States

The Cycle of Erosion (Ideal 11min si MP). Principles of erosion; development of valleys through youth, maturity, and old age.

It Can Happen Here (Harry Ferguson, Inc. 35min sd MP). Dramatized presentation of the mutual dependence of both farmer and businessman on the sustained productivity of the land; explains modern methods of undertaking soil conservation work.

This Is Our Land (Ethyl 26min sd MP). Highlights the importance of soil conservation; shows effect of overcropping and water and wind erosion; numerous ways to remedy these conditions.

Masters of the Soil (Ethyl 25min sd MP). Dramatized presentation of a farm family that learned we can be masters of the land,

while using it and saving it for the future, rather than let erosion of the soil determine our destiny.

The River (USDA 30min sd MP). Dramatic documentary of the Mississippi from pioneer days of river commerce to recent floods and erosion disasters; need for conservation.

A Heritage We Guard (USDA 30min sd MP). Early exploitation of wildlife and land for more crops; interrelation of wildlife and soil conservation.

Save That Soil (American Potash 28min sd C MP). Depicts early South; the results of the one-crop system and the reclamation and conservation of Southern soils through the use of legumes and modern methods of soil management.

Chapter 2—Extent of Erosion

Soil Erosion and Its Control in Orchards (DA FS). Shows how runoff and wind ruin orchards by gullying and drifting soil; control of such erosion by preventive practices and the use of brush mulch.

Under Western Skies (International Harvester 30min sd C MP). Presents the story of natural resources in the Far West and the conservation measures being taken to protect them; emphasizes soil and water conservation.

Chapter 3—Effects of Erosion

Soil Erosion (MOT 6min sd MP). Gives a vivid impression of the results of soil erosion; illustrates control techniques.

Muddy Waters (USDA 11min sd MP). Story of land use and abuse in Southwest; how grazing and farming depleted soil-binding vegetation.

Building Back (Allis-Chalmers 25min sd C MP). Shows how erosion is robbing us of our wealth; explains how we can prevent

this destruction by soil conservation, contour farming, and cover crops.

Flood! (USDA 11min sd MP). Portrays the recurring rural and urban damage caused by floods, including costly sedimentation of reservoirs, farmlands, and city properties; presents conservation measures that are being adopted on uplands to discourage floods at their source.

Grassland (USDA 11min sd MP). Discusses soil conservation on grazing lands of Southwest; methods of attacking evils of overgrazing.

Wind Erosion: Its Control on the Southern Great Plains (USDA FS). Portrays erosion starting in a number of ways and leaving a varied and tragic trail; shows how to prevent and control it by practices that save rainfall and soil.

Chapter 4—How Erosion Takes Place

Soil and Life (Case 11min sd C MP). Describes formation of soil over millions of years and how erosion can ruin it in a very short time; emphasizes practical measures being employed by modern conservationists.

Chapter 5—Rates of Erosion and Runoff

Fungi Snare and Destroy Nematodes (USDA 11min sd MP). How certain fungi devour nematodes and organic matter is broken down to enrich soil.

Chapter 6—Climate and Soil Erosion

Rain on the Plains (USDA 11min sd MP). Effects of wind erosion on land; reclamation steps; measures to conserve rainfall.

Work of the Atmosphere (EBF 11min sd MP). Shows how the atmosphere plays a part in altering the earth's surface through erosive action of the wind and sandblast action on rocks and trees; how it works with surface water.

Formation of the Soil (EBF 15min si MP). Indicates forces of erosion and weathering; shows processes of soil formation.

Chapter 8—A National Program of Soil Conservation

Food and Soil (USDA 11min sd C MP). Highlights of soil conservation in the United States.

Permanent Agriculture (International Harvester 30min sd MP). Latest methods of soil conservation.

In Common Cause (USDA 20min sd MP). Shows what soil conservation districts have accomplished; how they are formed and operated; and the big job yet to be done in the program for increasing crop production and saving soil.

Reclamation in the Arid West (USDI 11min sd MP). Shows projects on western deserts, Boulder and Grand Coulee Dams; effect on farm family.

For Years to Come (USDA 20min sd C MP). Changeover from old straight-row method to modern conservation farming methods; contour plowing.

Chapter 9—Planning for Conservation of Soil and Water

Planning to Prosper (Allis-Chalmers 22min sd C MP). Presents proper soil management, stressing contour farming and terracing.

Know Your Land (USDA 10min sd C MP). Presents in a simple way the principle of land classification; identifies the eight classes of land and explains that each land class has its proper use and treatment.

Green Acres (National Fertilizer 20min si C MP). Emphasizes pasture improvement; grazing of various livestock and typical pastures.

New Ways in Farming (MOT 15min sd MP). Shows the effect of depression, dust storms, floods, and erosion on farm lands; illustrates how average farm, properly managed, can be a source of good living, health, and independence.

No Idle Acres (MDC 20min sd C MP). Story of the use and misuse of lands in Michigan with suggestions for the future.

Chapter 10—Use of Vegetation in Soil and Water Conservation

Putting Plant Food to Work (National Fertilizer 20min sd C MP). Development of fertilizer application; problems encountered; movement of fertilizer in soil; results obtained from correct methods.

Reseeding for Better Grass (CFC 11min sd MP). How to turn coarse pasture lands into good grazing lands by reseeding.

Harvests for Tomorrow (USDA 30min sd MP). Use of soil-building practices in New England with emphasis on grass and legumes.

The Life of the Soil (National Fertilizer 30min sd C MP). Need for growing legume and nonlegume cover crops; how man has adapted nature's methods to improve soil.

The South Grows Green (USDA 25min sd C MP). Shows how crop diversification is replacing the old, destructive one-crop system and the resulting production.

Tree Planting and Land Use (USDA FS). Shows how mistakes in land use result in loss of yields and soil; ruined land may be made useful with plantings, adapted to sites and proper care as they develop.

Soil Conservation Benefits Wildlife (USDA FS). Nature reclaims areas saved by soil conservation and so provides cover for game, fish, and wildlife.

The Farm and the Farm Woods (USDA FS). The farm woods are as much a crop-producing unit as any other part of the farm and with proper care and management yield high-quality products for sale and home use.

Farm Woods; a Safe Crop for Steep Lands; Upper Mississippi Valley (USDA FS). Shows which practices should be avoided to prevent erosion and others which should be used to check erosion on farm woodland.

Chapter 11—Contouring

Level Farming on Sloping Fields (Case 10min sd MP). Shows the application of modern power farm equipment to the latest recommended soil conservation practices with references to contour farming, contour strip farming, and pasture improvement.

Contoured Acres Fight (USDA FS). Farm on the level and save water, fertilizer, and soil; contoured acres will grow more crops.

Corn Belt Farmers Fight Erosion (USDA FS). Shows how the Corn Belt farmers fight erosion by contour farming, terracing, rotation, planing, diversion drainage, and check dams.

Chapter 12—Terracing

Terracing in the Northeast (USDA 11min sd MP). Construction and uses of terraces and other erosion control measures.

Broad Base Terracing (Case 12min sd C MP). Shows how to build a terrace with a one-way disk plow.

Build Good Terraces (Case 12min sd MP). Describes how to build a modern channel-type terrace with a two-bottom moldboard plow.

Chapter 13—Channels and Outlets

First Things First (USDA FS). Shows how grassing of waterways controls erosion; contouring holds runoff on land of gentle slope; grassed waterways direct it on greater slopes.

Chapter 14—Gully Control

Establishment and Maintenance of Grassed Waterways (USDA FS). Gullies cause destruction; slope and seed them to serve as waterways.

Chapter 17—Wildlife and Soil Conservation

Home on the Range (USDA 11min sd MP). Government plans for control of erosion in the public domain; activities in control of erosion; such as flood control, protection of grass, construction of driveways, the seeding of overgrazed areas.

Wildlife Management through Soil Conservation in the Northeast (USDA FS). Engineering practices and planting save land and make useless land a refuge and source of feed for wildlife.

Soil and Water Conservation by the Beaver (USDA FS). Tells the history, habits, and economic relations of the beaver with particular reference to farm and forest lands.

Chapter 20—Farm Drainage

Wetlands (USDA 11min sd MP). How some wetlands can best serve as they are; others can be used for farming by proper water control and land drainage.

Chapter 21—Farm Irrigation

Snow Harvest (USDA 25min sd C MP). Shows how the Soil Conservation Service and the Forest Service measure the winter snowfall in the western mountains so that the amount of water available for farmers the next summer can be accurately predicted.

Irrigation (EBF 15min si MP). Gives impression of the need for and result of irrigation; suggests sources of water used for irrigation and methods of conduction to fields where it is used.

Irrigation Farming (EBF 11min sd MP). Irrigation canals, furrow and flooding methods.

Chapter 22—The Place of Trees and Shrubs in Soil and Water Conservation

Story of the Forest (B&H 40min sd MP). Its vital role in water control and soil erosion; early lumber industry and later reforestation efforts.

Sources of Films Listed Above

Allis-Chalmers Mfg. Co., Advertising & Public Relations Dept., Milwaukee 1, Wis.

American Potash Institute, 1155 16th St. N.W., Washington 6, D. C.

B&H—Bell & Howell Co., 1801 Larchmont Ave., Chicago 13.

Case, J. I. Company, Racine, Wis.

CFC—College Film Center, 84 E. Randolph St., Chicago 1.

EBF—Encyclopaedia Britannica Films, Inc., 20 N. Wacker Dr., Chicago 6.

Ethyl Corp., 405 Lexington Ave., New York 17.

Harry Ferguson, Inc., 15020 Woodward Ave., Detroit, Mich.

Ideal Pictures Corp., 28 E. Eighth St., Chicago 5.

International Harvester Co., 180 N. Michigan Ave., Chicago 1.

MDC—Michigan Dept. of Conservation, Educational Div., Lansing 13, Mich.

MOT—March of Time, 369 Lexington Ave., New York 17.

National Fertilizer Assn., 616 Investment Bldg., Washington, D. C.

USDA—U. S. Dept. of Agriculture, Motion Picture Div., Washington, D. C.

USDI—U. S. Dept. of the Interior, Motion Picture Div., Washington, D. C.

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